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Engineering Colleges and Secondary Schools

By S. S. STEINBERG

Vice President of the Society; President, Engineering College Administrative Council
Dean, College of Engineering, University of Maryland

It is common practice in engineering and industrial operations to sublet to others the preparation of component units which form a part of the completed structure. When this is done, specifications are carefully prepared for guidance so that the necessary requirements as to quality and quantity are fulfilled, and to insure efficient performance when incorporated in the structure as a whole.

While this principle is well known to engineering educators, they do not seem to have availed themselves of it to any great extent insofar as it concerns the preparation of students in secondary schools who later come to the engineering colleges for training to enter the engineering profession. We find too ofter that high school preparation in the subjects fundamental to engineering are so inadequate that large groups of students cannot complete our curricula in the four years normally allotted to them.

It was with these thoughts in mind that the General Council of the Society at its last meeting took action to reorganize the Committee on Secondary Schools, formerly an independent unit, and to place it under the Engineering College Administrative Council. It was felt that since the relationship between the engineering colleges and the secondary schools is of vital importance to engineering education, it should be the direct concern of engineering college administrators, namely, the Deans of Engineering. The Committee as reorganized includes in its membership representatives of the secondary schools in the fields of English, Mathematics, Chemistry, and Physics.

This closer relation between engineering colleges and secondary schools should result in many advantages mutually beneficial to both groups. Among these is need for expansion of secondary school offerings in Mathematics, Chemistry, and Physics; for inauguration of programs in the colleges for the training of high school teachers in Mathematics and in Science; for encouragement of secondary school teachers interested in engineering education to become members of our Society; for holding meetings of sections and branches of the Society jointly with high school principals, advisors, and teachers; for determination of ways and means by which secondary schools may compete more successfully with industrial employment and thereby attract and hold the more competent teachers of Mathematics and of Science; by acquainting secondary school officials and students more fully regarding the engineering profession and its requirements; and finally, by making available to high school authorities and students pertinent information concerning the engineering colleges in their immediate vicinity.

What Management and Economic Courses Should be Included in All Engineering Education?*

By EUGENE L. GRANT

Professor of Economics of Engineering, Stanford University

The question stated in the title of this paper is of particular interest whenever engineering curricula are being scrutinized and revised. My answer to it consists of a list of seven courses, each of which deserves serious consideration by the planners of curricula:

Accounting (including an introduction to cost accounting)
Business Law
Elementary Economics
Engineering Economy
Industrial Organization and Management
Industrial Relations
Statistics

These are temporarily listed in alphabetical order. I propose to comment briefly on the general objective to be served by all of these courses, to consider their order of priority, and to make some remarks about their relationship to certain practical aspects of curriculum planning.

My list involves two additions to a similar list prepared in 1937 by a group of engineering teachers who attended the Economics Summer Camp sponsored by the S.P.E.E. and held by Stevens Institute of Technology at Johnsonburg, New Jersey. Many of this same group had attended the Economics Summer School for Engineering Teachers given by the S.P.E.E. on the Hoboken campus of Stevens in 1932, and the Economics Summer Camp in 1936. Most of us were primarily teachers of technical engineering subjects who had developed a side-interest in the management and economic content of engineering education. We were in complete agreement that if we could write engineering curricula, we would try to include the first five of the courses which I have placed on my list. The events of the past ten years have emphasized the importance to engineers of Industrial Relations and Statistics, the last two courses on my list. I believe that today a group of engineering teachers similar to our 1937 Stevens group would include all seven courses on my list.

As I see it, each of these courses is, from the viewpoint of its objective in the curriculum, something like the service course in the elements of electrical engineering given to civil and mechanical engineering students or the service course in the elements of heat engineering given to electrical and civil engineering students. Each is an introductory course to a broad field. In each field, it is important that the

* Presented at the Pacific Southwest Section meeting, Pasadena, California, December 28, 1946.

student understand certain basic principles and that he also be introduced to current devices and practices. In each, the student should be given a background which will help him in further reading and study of the subject.

There is, however, a significant difference between these seven courses and the service courses in electrical engineering and heat engineering. The student is already aware that he may have to deal with electrical machines and with heat engines as part of his engineering career, and he has had some introduction to basic principles in his course in physics. On the other hand, without introductory courses in these economic and management subjects, he is frequently not conscious of the existence of important problems with which he will have to deal; when he later meets these problems he may not be conscious that there are certain principles which he may use in their solution.

The Investigation of Engineering Education, 1923–29, stimulated consideration of the place of management and economic subjects in the engineering curriculum. The report on this Investigation disclosed (p. 242) that the most outstanding criticism of engineering curricula by recent engineering graduates was the lack of training in business and economic subjects. It also disclosed the fact, confirmed by many later studies, that although engineering graduates usually started in activities that were primarily technical, they rapidly shifted to duties that were primarily administrative. Within ten years after graduation, more than two-thirds were engaged in administrative work.

It has sometimes been suggested that management and economic courses be given only to those students who seem most likely to be in the group which soon becomes engaged in primarily administrative work. This suggestion fails to recognize the importance of all of these subjects to the engineers whose duties are primarily technical. For example, many choices involving relative economy of engineering alternatives are made by the designer; to make these choices intelligently he needs the techniques of engineering economy. Or consider the question of tolerance limits and their interrelationships; these cannot be judged properly without a knowledge of the techniques of statistics. (See Colonel Leslie E. Simon's interesting paper, "On the Teaching of Quality Control to Engineers," in the October 1946 issue of the JOURNAL OF ENGINEERING EDUCATION.)

Even though there should be general agreement that all these subjects are desirable ones for all engineering students, it is evident that there are practical difficulties in fitting them into the engineering curriculum. This raises the question of order of priority. The Stevens group which made the original list of five courses in 1937 was unanimous in the conclusion that if a place in the curriculum could be found for only one of these courses, that course should be Elementary Economics. We were also unanimous in agreeing that our second choice was Engineering Economy. Beyond this point there was no agreement whatever. Accounting, Business Law, and Industrial Organization and Management had equal numbers of supporters for the third position on our priority list.

A somewhat different view on order of priority is found if we examine the 1945 Progress Report of the Commit-

tee on Engineering Education of the A.S.C.E. (See *Proceedings*, A.S.C.E., March 1946, pp. 386–396.) A questionnaire designed by the Cooperative Committee on Civil Engineering Education of the S.P.E.E. was sent to a group of A.S.C.E. members. Part of the questionnaire asked for a rating of some 77 subjects which might be taught to civil engineering students as of "great importance, moderate importance, or little importance." The ratings by 1035 civil engineers of the subjects corresponding most closely to the seven courses on my list were as follows (a rating of 3.00 corresponds to an average rating of great importance, 2.00 to an average rating of moderate, and 1.00 to little):

Engineering economy	2.44
Personnel and labor relations	2.30
Business law	2.19
Statistical analysis	2.18
Economic theory	2.14
Industrial management	1.93
Accounting	1.80

No doubt the relatively low rating of industrial management and accounting is due to the fact that the rating was done by *civil* engineers. I feel confident that mechanical engineers, for example, would place a considerably higher rating on these subjects.

My own experience with a course in accounting for engineering students leads me to a much higher rating of it than that given by the civil engineers. For a number of years I have taught a short course for engineers in the elements of accounting and cost accounting. I have also, at various stages in my career, taught about two-thirds of the courses given by one civil engineering department, all but two of the seven courses on my list of management and economic courses, and a number of advanced courses given to industrial engineering students. Among all of these courses, accounting has consistently through the years been the course which has brought me frequent comments from graduates who have spent a few years in industry to the effect, "That course certainly has proved helpful to me."

My own order of priority for the seven courses on my list is similar to that obtained by the group at Stevens. I believe that elementary economics and engineering economy are basic courses which should never be omitted from engineering curricula. Any choice that must be made among the other five courses seems to me to be very difficult, so difficult that it might appropriately be based on considerations other than the relative importance of the subject matter.

In the early 1930's, largely as a result of the Investigation of Engineering Education, the trend in curriculum making was toward more management and economic content. Sometimes, however, it happened that contemplated changes in this direction were never made because of the budgetary difficulties created by the depression. Today there are strong pressures on engineering curricula in other directions—for more fundamental mathematics and physics—for more advanced technical courses to keep pace with recent technological progress—and for more courses in the humanistic-social stem.

With reference to the humanistic-social stem, it might be remarked in passing that my group of seven management and economic courses does not entirely fit the currently popular classification of all courses into either the Scientific-Technical Stem or the Humanistic-Social Stem. Elementary

economics is clearly humanistic-social. The other six courses have definite broadening aspects and would certainly seem to contribute to the enlargement of the horizons of the engineering student. However, they do deal in part with definite tools and techniques. In some cases, out of deference to a formula used in curriculum-making, it may be considered essential to consider each course as included in one stem or the other. If so, a fair classification might be to consider Accounting, Engineering Economy, Industrial Organization and Management, and Statistics as being more largely scientific-technical. Industrial Relations properly taught would seem to be primarily humanistic-social. So also might Business Law, particularly if it is taught in such a way that a major objective of the course is to give the student a broad picture of what law is and how it operates.

With the many current pressures on engineering curricula, it is probably impracticable to require all engineering students to take the five management and economic courses which I have suggested as competing for the third place on the priority list. However, a practicable action, which has certain obvious psychological advantages over requiring the courses, is to give every student the opportunity to take all of these courses. That is, all of these courses should be available to engineering students, who should be permitted and encouraged to elect them, possibly as alternatives to certain specialized technical courses.

With the current increased tendency of engineering students to take one year of graduate work, it is particularly advantageous if one such course can be included in each graduate term. This helps to balance a program which otherwise might be entirely advanced technical courses. Moreover, all of these courses (with the possible exception of accounting which may be taught effectively to sophomores and juniors) profit greatly by the increased maturity of the student.

Accrediting Technical Institutes

By H. P. HAMMOND

Dean, School of Engineering, Pennsylvania State College

The program of accrediting technical institute curricula which is now in progress under Engineers' Council for Professional Development is an outgrowth of the Wickenden-Spahr report on technical institutes published by this Society in 1930.* The program has the broad purpose of serving "industry and the engineering profession generally by stimulating the development of a better balanced system of technical education" throughout the United States, a need which the report emphasized. A necessary step in that direction is the establishment of means of recognition of education and training of technical institute type by the engineering profession, government, industry, and the public. The program of accreditation has that purpose.

Education of technical institute type has been a neglected sector of technical education in this country for many years. Whereas, in other industrial nations there have been both more schools and more students engaged in technical institute education than there have been in professional engineering education, emphasis in the United States has been in the opposite direction. There are reasonably adequate provisions in this country for vocational training, and there is a sound and strongly established system of engineering education at college level, but there are far too few strong institutions having the purpose of training for occupations in the area between secondary education and vocational training on one side and professional engineering education on the other. Competently conducted surveys of the relative needs for personnel trained for various types of technical occupations have shown that for every engineering college graduate, American industry could use to advantage from three to five graduates of the briefer and more practical programs of the technical institutes. At present, a good many engineering college graduates are employed in positions which technical institute graduates could fill acceptably. The attitude of the general public, which is inclined to think only of college education as suitable for young people going beyond high school, is in large measure responsible for this, and this is due, in part at least, to lack of a suitable authoritative source of recognition of technical institute education such as exists in England under the joint jurisdiction of the national Board of Education and the national engineering societies. One evidence of this condition in the United States is to be found in the conversion into engineering colleges of a number of well endowed institutions which the founders

* See Volume 2 of the Report of the Board of Investigation and Coordination, Society for the Promotion of Engineering Education, 1928–1929.

established as technical institutes. The present program of accreditation is intended to aid in remedying this situation.

When E.C.P.D. was established the words *engineering schools,* instead of *engineering colleges,* were chosen to designate one of the major fields of the Council's activities because it was believed that eventually the Council might find it advisable to aid in the development of a sounder system of technical education at intermediate levels. This would aid, in turn, in clarifying the aims, purposes, and scope of collegiate engineering education. While it was the hope of the present writer at that time that the technical institutes themselves would set up a program of accreditation having the broad purposes mentioned above, this did not occur since there was no organized group of institutions to undertake it. When a meeting of representatives of a number of institutions offering technical institute programs was finally held in 1940 to discuss the matter, it was voted to request E.C.P.D. to undertake the movement since it was the most soundly established agency that could do so. Four years of war intervened between the 1940 meeting and final action by E.C.P.D. on the petition, a critical period so far as many institutions interested in the undertaking were concerned. At present, however, the program seems to be soundly established. In that interval, also, the National Council of Technical Schools, comprising chiefly proprietary institutions, set up its own accrediting procedure, which is now serving a very useful purpose, though meeting somewhat different needs and less universal in its application than the E.C.P.D. program.

Since the active beginning of the E.C.P.D. program early in 1945, curricula of seven institutions have been recognized, those of six others will be considered during the present academic year, and inquiries indicate that a number of additional schools will apply for recognition in the near future. Though progress has been slow, standards and procedures of accreditation have been well established, committee personnel has been selected in all regions of the country, and experience in evaluating the many and diverse types of institutions and programs has been gained.

In order to acquaint readers who are not familiar with the annual reports of E.C.P.D., with the characteristics of technical institute programs, condensations are given below from various sources of literature on the subject. A more thorough, and in many respects still up-to-date, treatment of the subject will be found in the S.P.E.E. report of 1928–1929, to which reference has already been made.

Definition of Technical Institute Curricula

E.C.P.D. defines the purposes and characteristics of curricula of technical institute type as follows:

(1) The purpose is to prepare individuals for various subordinate or auxiliary technical positions or lines of activity encompassed within the field of engineering. The scope of these programs is more limited than those required to prepare persons for careers as professional engineers.

(2) Curricula are essentially technological in nature, based upon principles of science, require the use of mathematics beyond high school, and emphasize rational processes rather than rules of practice.

(3) Programs of instruction are briefer, and usually more completely technical in content than professional curricula, though they are concerned with the same general fields of industry and engineering. They do not lead to the baccalaureate degree in engineering. Such designations as Engineering Aid, Technical Aid, Associate in Engineering, and Engineering Associate are appropriate designations to be conferred upon the graduates of programs of technical institute type.

(4) Training for artisanship is not included within the scope of education of technical institute type.

Institutions operated under a variety of auspices offer programs of instruction falling within the boundaries defined by the foregoing paragraphs:

(1) Technical institutes, endowed or publicly supported, and operated either on a full-time or part-time basis. Wentworth Institute and Ohio Mechanics Institute are examples.

(2) Junior colleges offering terminal programs.

(3) Evening sessions of colleges and universities, such as those of Drexel Institute and Pratt Institute.

(4) Extension divisions of colleges and universities which offer work in extension centers, such as Purdue University and The Pennsylvania State College.

(5) Proprietary schools, operated by individuals or corporations, such as the Bliss Electrical School and Capitol Radio Engineering Institute.

(6) Schools or training divisions operated by or in close affiliation with industrial concerns, such as Northrop Aeronautical Institute and the R. C. A. Institute.

(7) Schools operated by divisions of government, such as the maritime academies.

(8) Correspondence schools, such as the International Correspondence Schools and the extension divisions of certain colleges and universities.

In 1940–1941 more than 150,000 students were enrolled in curricula of technical institute type offered by the 250 or more institutions of the types above named. More than half of these were pursuing correspondence courses, however, and a considerable portion of the remaining enrollments were in part-time evening sessions. The present total enrollment in technical institute pograms is not known but it is undoubtedly much larger that it was in 1940–1941. Part of this gain has been in extension work of some of the colleges and universities. In the opposite direction, there has been a recent tendency for junior colleges to extend their pre-engineering and terminal programs to four-year curricula leading to degrees.

Requirements for Accreditation

E.C.P.D. has established the following requirements for accreditation of a curriculum of technical institute type:

(1) *Duration.* Not less than one academic year of full-time work, or its equivalent in part-time work; a total of not less than 960 contact hours of instruction.

(2) *Requirements for admission.* High school graduation or its equivalent (an integrated program extending from the 11th to the 14th grades, inclusive, will be considered).

(3) *Curricula.* Technological in nature, employing the principles of science and the techniques of mathematics to the solution of practical problems (but not of ex-

tent equivalent to curricula leading to baccalaureate degrees).

(4) *Instruction* by accepted class and laboratory or correspondence methods.

(5) *Teaching staff* qualified as to training and experience and sufficient in numbers to provide adequate attention to each student.

(6) *An organized school* or division of an institution or industry devoted to the specific aim of providing technical institute programs.

(7) *Physical facilities* adequate for the purposes of the curricula offered.

The E.C.P.D. Subcommittee on Technical Institutes has adopted procedures of accreditation which are essentially similar to those of the Committee on Engineering Schools. To these, however, have been added, as approved by E.C.P.D., the two following stipulations:

The Subcommittee on Technical Institutes will not recommend for accrediting as a curriculum of technical institute type any curriculum for which the claim is made that it produces qualified engineers.

It is not the province of the Subcommittee on Technical Institutes to pass upon curricula that lead to baccalaureate degrees. This is the function of the Committee on Engineering Schools.

Questions are often asked as to the types of occupations for which technical institute programs supply personnel. These may be characterized as auxiliary to but not lying within the field of professional engineering for which a baccalaureate degree program would supply appropriate preparation. Selections from a more extensive list of typical occupations of this type follow:

Checker
Computer
Dispatcher
Draftsman
Engineering aid
Estimator
Foreman
Heat treater
Inspector
Laboratory technician
Liaison man
Maintenance technician
Metalographer
Methods man
Power dispatcher
Process specialist
Specifications writer
Substation operator
Superintendent
Surveyman
Technical assistant
Technical clerk
Technical illustrator
Technical salesman
Technical writer
Tester
Time study analyst

Accreditation Committee Personnel

The Subcommittee on Technical Institutes comprises eight members. One member presides as chairman of the regional inspecting committee in each of the eight regions into which the country is divided for operating purposes of the program. The list of regions and of regional chairmen follows:

Region 1. New England and New York; William C. White, Northeastern University.

Region 2. Pennsylvania, New Jersey, Delaware, Maryland, District of Columbia, Virginia, West Virginia; H. P. Hammond, The Pennsylvania State College.

Region 3. Ohio, Michigan, Indiana, Kentucky; C. J. Freund, University of Detroit.

Region 4. Southeastern States; E. H. Rietzke, Capitol Radio Engineering Institute.

Region 5. North Central States; John

T. Faig, Ohio Mechanics Institute.
Region 6. South Central States; C. W. Beese, Purdue University.
Region 7. Northwestern States; Nicholas Ricciardi, Sacramento City College.
Region 8. Southwestern States: L. M. K. Boelter, University of California at Los Angeles.

All except two members of the committee are affiliated with institutions that offer technical institute programs. The writer hopes that eventually an organization of technical institutes, perhaps within the American Society for Engineering Education, may have an active affiliation with the accrediting program.

Problems and Trends

What are some of the problems and trends within the field of technical institute education and training? The following have presented themselves thus far in the program of accreditation:

The tendency already mentioned for some of the junior colleges to convert their terminal technical programs into degree-conferring curricula.

The difficulty which arises within a single program of serving both the aims of terminal training and of pre-professional education.

The trend—in the opinion of the writer a healthy and desirable one—to take the benefits of terminal type training into the home communities of students, either under state, university, or local auspices. Examples are to be found in Indiana and Pennsylvania where the land grant institutions are establishing branch technical institutes in industrial centers, and in New York where technical institutes are being established directly under State auspices and control.

Problems arising from the difficulty of establishing clear objectives and appropriate methods of instruction peculiar to technical institute needs. Often the faculty is made up of engineering graduates who have difficulty in adjusting themselves to technical institute objectives.

Difficulties incident to nomenclature. As already stated, E.C.P.D. will not recognize an institution that makes the claim of graduating "qualified engineers." The committee suggests such designations as *technical aid* and *associate in engineering* (paralleling the designation *associate in arts* which has been in use for some years) for graduates of technical institute curricula. The committee dislikes the use of the term *engineering* in designating technical institute curricula, but this practice is of such long standing among many sound and reputable institutions —as in the form *industrial mechanical engineering,* for example—that it seems impracticable to insist that it be not used in connection with accredited curricula.

The ever present problem of financing technical institute programs. Properly done, technical institute work is of the same order of cost as engineering college work, yet high tuition fees are often not feasible (most proprietary schools are exceptions in this respect), public support is often meager, and income from endowments is shrinking while costs are rising. This condition points in the direction of state or municipal support on a more widespread basis than at present.

The need, which should be met as soon as practicable, for appropriate forms of recognition of the technical institute graduate by government (civil service), the organized engineering

profession, and industry, so that he may fit into an appropriately dignified sphere of technical life and be accepted for public and industrial positions of suitable type and rank.

Generally speaking, technical institutes are more highly specialized than engineering colleges. A good many of them offer work in but a single field, such as radio or aeronautics. They respond more quickly to public demand than do colleges and universities. Some of them, therefore, are peculiarly susceptible to changes in the "market" for graduates. In some instances finances are less stable than is the case with colleges and universities, though this is not the case with many of the institutes. Contrary to some public opinion, many of the proprietary schools offer highly effective programs of instruction, and the efficiency of their operations might well serve as guides to some colleges and universities.

Divisions

From the "Machine Design Clearinghouse" published by the MECHANICAL ENGINEERING DIVISION, we received these helpful suggestions:

It may be of value to review the purposes of examinations. Perhaps our procedures are habitual and no longer serve the purposes of good pedagogy. Are we giving the exams in the most effective manner to get the most information with the least amount of instructor effort? Or are we not?

Do our examinations . . .

Separate the sheep from the goats?
Test the student's ability to calculate, or to think?
Measure his ability to solve Algebra or Machine Design problems?
Afford him an opportunity to express his knowledge?
Admit of too much interpretation by the student?
Require an unduly large amount of time for preparation and grading by the staff?
Reveal any muddy thinking on the part of the person who prepares them?
Require memorization of data most of the students will never need?
Appear to the student as a grading process or as an ordeal?

Have you considered these points? What special features do you use to facilitate your grading?

The Fifth Regional Surveying Teachers Conference is to be held August 26, 27 and 28, 1948 under the auspices of Committee VIII, Civil Engineering Division, A. S. E. E. and the Cooper Union for the Advancement of Science and Art. This is the first conference of this type to be held in eight years.

Special Engineering Requirements of the Small Industry

By G. L. HARTMAN

Vice President and General Manager, Milwaukee Flush Valve Co.

There comes a time in the life of every small industry when it emerges from adolescence and blossoms forth into a mature organization. This is not accomplished without the initial trials and tribulations of developing a product, promoting the sale of it, and building up production capacity to satisfy an accelerating demand. It is during this building up period that it becomes evident that departments must be expanded and a definite plan formulated for the infiltration of new talent to keep pace with the growth of the industry, to provide for understudies to department heads, and to fill new positions created. Unfortunately, many small industries do not avail themselves of many opportunities open to them for obtaining suitable candidates to fill the newly created positions. They are not aware of the availability of engineering talent graduated from our Engineering colleges every year or feel, perhaps, that they cannot compete with the larger industries who have, for many years, dominated the field of engineering graduate employment, and fail, therefore, to investigate the possibility of obtaining such talent.

The Larger Corporations Dominate the Field

The larger and older corporations, such as General Electric, Allis-Chalmers, Westinghouse, Standard Oil, the aircraft manufacturers, and others have done a splendid job of recruiting engineering talent directly out of the schools; they have also set up training programs designed to fit engineering graduates into the many jobs for which they are continually seeking suitable candidates. The officials of these companies are well known on college campuses through the prominence of their offices and their active interest in the work of the Society for the Promotion of Engineering Education. This has contributed heavily toward the notion on the part of the officers and faculties of our engineering colleges that the large industries are representative of all engineering industries in spite of the fact that the greater percentage of engineering graduates gravitate to the smaller corporations. The faculties therefore tend to assume that the scholastic requirements, standards, etc. of the larger industries must be the requirements of all industry.

Elaborate training programs have been set up by the larger corporations. They are willing to train graduate engineers over a period of 2 or 3 years, which gives them an opportunity to study the ability and capacity of each student for the purpose of assigning him to research or other technical work, executive duties or other work for

which he seems best suited. These students are not necessarily picked for any one job, but rather on a general basis, expecting that the training program will weed out the unfit and uncover talent usually not easily recognizable during the students' undergraduate work.

Can a Small Industry Compete?

Definitely! While it is true that a large industry has many openings for engineering talent and many separate departments which may be used for training purposes it is also true that the training must, of necessity, be highly specialized in each department. Compare this with a smaller industry in which there are fewer departments, but in which department activities and functions are more diversified than in larger industries where separate departments are organized. The student training in such a department of diversified activities enjoys wider opportunities. For example, in a smaller industry the Engineering Department is, of course, in charge of all design work but also controls the activities of the experimental and research staff and, in some instances, may have control of inspection or similar functions. This gives the trainee the opportunity of observing the relationship between the several distinct activities which in many larger industries are separated and function under separate department heads.

Because the student in a small industry is exposed to a multiplicity of duties in any one department, his training may be accelerated. It may be adjusted to the needs of the company, allowing more or less time in the various departments in accordance with the immediate requirements of the employer and also dependent, to a great extent, on the adaptability of the trainee. The trainee's progress may be closely watched. Consequently the employer knows within a reasonably short time whether the student has the proper qualifications and can determine whether he can fill any one of the jobs which may be on the expansion list. Not only does the student have the privilege of an accelerated training, but he also has the opportunity of meeting and associating with the department heads and executives of the company.

All of these advantages give the small industry an edge in attracting suitable talent. It is an argument most students overlook in their desire to associate themselves with a large industry.

How to Obtain Suitable Engineering Talent

There is no one method for recruiting candidates which is most effective for any one company, nor for any one industry, nor for small companies as a group. Therefore, a recounting of experiences which have produced results in some cases may suggest a possible solution to any organization facing the problem of obtaining student engineers.

Probably the easiest and most direct method is to steal a page out of the book of a larger corporation by making the acquaintance (if it is not already a personal friendship) of a large corporation's personnel director or similar official for the purpose of studying the methods employed by him and discussing with him how some of these methods may be employed by the small organization. He is in position to advise which engineering schools are best

able to produce the engineering talent required, the proper school officials to contact as well as the procedure to follow which will aid in a proper selection. To go one step further, it would not be out of order to request the privilege of accompanying him on a recruiting tour of several schools which would be of inestimable value in making the proper faculty contacts. Being introduced to such faculty members by one who has contacted them for years has the effect of producing immediate results because it more quickly elevates the contact to a more personal relationship between the faculty member and the interviewer representing the smaller company.

If conditions are such that it is not practical personally to visit the schools (although such visits are definitely recommended), the recruiting agent for the larger organization may volunteer to "steer" likely candidates in the direction of the smaller company. This approach is certainly not too effective but it is far better than allowing chance to dictate whether or not engineering candidates will seek employment with a small organization. Pre-selection by a personnel director experienced in such work may bring surprising results.

In some cases, contacts with university officials may be made directly rather than with outside help, but previous acquaintance with faculty members is then quite essential or it becomes necessary to cultivate such acquaintance. Because of specialization in mechanical, electrical, civil, chemical, and other fields of engineering, it is desirable to contact not only the officers of the engineering college, but also the department heads, professors or instructors who, in most cases, are intimately acquainted with individual students and know their scholastic accomplishments as well as their extracurricular activities which frequently carry much weight in evaluating the student's qualifications for a definite job the interviewer has in mind. With the limited time at his disposal, the interviewer cannot, of course, interview all graduates; he will follow, to some extent, the suggestion of school personnel and interview the students recommended by them, and such recommendation will depend upon their knowledge of the interviewer's company, its product, past history and possibility of growth, and of the job to be filled. The interviewer will need to furnish such information to the school authorities in considerable detail.

Up to a few years ago engineering colleges considered their job complete if their students were given an education according to prescribed standards, but lately the more progressive schools have taken the attitude that the job is not complete until their graduates have been properly placed. Usually this is accomplished by a college personnel director who makes it his business to contact industry, and since he is not personally acquainted with the students through classroom work, he has available sufficient information regarding each student to assist the interviewer in making his selection. This information is gathered in a card record giving a full description of the student; age, height, weight, etc., his parentage, his preparatory education, scholastic record in detail, his extracurricular activities, what percentage of his educational expenses had to be earned by himself and much other pertinent information. A picture of the student completes the record. Such a record, properly kept up to date, even after graduation, is of considerable

value in the pre-selection of candidates to be interviewed.

One further step has proven very effective in the case of a small midwestern manufacturing plant. This company invited some of the professors of the mechanical engineering department of a neighboring college to visit the plant with expenses fully paid to become more thoroughly acquainted with the product, by means of a trip through the plant to see at first hand the production equipment in full operation, and to study briefly the production personnel set-up and the engineering department, and finally to meet the top management and executive group.

The immediate results to be expected from such a trip, even though it may be brief, are as follows:

(1) It gives the professors and instructors a far better picture of the type of organization for which they must prepare students.

(2) It makes for more intelligent recommendation of candidates.

(3) School personnel and industrial management become better acquainted.

(4) It promotes mutual assistance.

(5) The teaching profession gains a better understanding of manufacturing problems and, conversely, industry becomes more interested in the affairs of the university.

Unfortunately many of our professors have only an academic interest in engineering education and our industrialists are too busy with their own problems, which circumstances have mitigated against proper mutual acquaintance.

This acquaintance phase of the procedure may be termed the preliminary persuasion and conviction program which later must be continued with the candidate. The small company is usually at a disadvantage in competing with the larger company because the smaller company may be totally unknown and, as far as the student is concerned, the offer of the larger company is more attractive unless it can be proved that the smaller company offers the better opportunities. It is a selling job.

What Specifically Does a Student Want When He Leaves School?

That question cannot very well be answered satisfactorily because each individual has his own idea of what is important to him. It therefore becomes necessary to gather together sufficient data fully to describe the company and the opportunities offered, which may include the following:

(1) The company
   a. Its history
(2) The product
   a. Where used
   b. Present volume
   c. Future expansion
(3) The personnel in the company
(4) The advantages offered by a small company.
   a. Job opportunities in the various departments.
   b. Job diversification.
   c. Advancement possible.
   d. Close association with department heads.
   e. Personal contact with top management.
(5) Salary

Properly presented, the case of the small company will not suffer in competition with the larger company. A good selling job is necessary and the results obtained are dependent upon the proper selection of a representative to do the interviewing. After selections have been made, a well-planned train-

ing program will pay dividends in providing junior executives to fill new openings in a growing organization and eventually step into the shoes of retiring executives.

A gradual infiltration of suitable talent, properly trained, will minimize the danger of financial ruin or internal decay and will, without question, build up a sound organization.

Sections and Branches

On Saturday, April 10, Ohio State University was host to the Spring meeting of the Ohio Section of the American Socitey of Engineering Education. Following an address of welcome by Harvey H. Davis, vice president of Ohio State University, the one hundred and twenty-five members present heard talks and saw a demonstration of fundamental facts in visual training and education. The speakers were Samuel Renshaw, Department of Phychology at Ohio State University, and W. C. Schwarzbek, Employee Relations Department of the General Electric Company. After luncheon at the Faculty Club, Dean Charles E. MacQuigg, President of A.S.E.E., spoke on "Education for Engineering Plus." The afternoon session closed with an address by Carroll L. Shartle, Personnel Research Board, Department of Psychology, Ohio State University.

Officers elected for the Spring 1949 meeting to be held at Ohio University at Athens where as follows: Chairman, E. H. Gaylord, Ohio University; vice-chairmen, S. M. Spears, Dean of Fenn College, and Samuel R. Beitler, Ohio State University; secretary, Wilson R. Dumble, Ohio State University.

The Michigan State College Branch of the A.S.E.E. held a meeting on February 26, 1948, with Chairman J. M. Apple presiding. The evening program consisted of a roundtable discussion of "Criteria for Judging the Competence of Engineering Faculties." Speakers included H. B. Dirks, Dean of Engineering, and L. G. Miller, Head of the Mechanical Engineering Department.

Report of the George Westinghouse Award Committee for the Year 1946–1947

By HOMER L. DODGE

Chairman of the George Westinghouse Award Committee

The George Westinghouse Award in Engineering Education was first announced on March 25, 1946. It consists of an award of $1000 in cash and a suitable certificate given yearly by the American Society for Engineering Education to recognize and encourage outstanding contributions to the teaching of students of engineering. The funds which make the award possible are supplied by the Westinghouse Educational Foundation.

The first award was made in June, 1946, to Professor James Norman Goodier of Cornell University.

Following the procedure established and found to be workable the previous year, a sub-committee consisting of Dean H. P. Hammond, Professor A. D. Moore, Mr. C. A. Powel, President Homer L. Dodge, and Professor H. O. Croft, *ex-officio,* was appointed to give preliminary consideration to the candidates. This group, with Professor Croft absent, met in Pittsburgh on March 19, 1947. Secretary F. L. Bishop sat with the committee during most of its deliberations.

Nine new nominations (one involving four individuals) were considered, as well as the outstanding nominations of the previous year. Four candidates were selected for consideration by the full committee.

The complete nomination material for each of these men was made available to all members of the committee. Each member of the committee was asked to indicate his first, second, third, and fourth choices among the candidates. The result of the balloting gave the George Westinghouse Award for 1947 to Professor Benjamin R. Teare, Jr., of the Carnegie Institute of Technology, and the award was made at the annual dinner of the A.S.E.E. in Minneapolis in June, 1947.

A joint luncheon meeting of the committee with the Lamme Medal Committee was held in Minneapolis, at which it was possible to compare notes and general policies. There was also considerable informal discussion among members of the committees.

The complete list of members of the George Westinghouse Award Committee for the year 1946–47 is as follows: Homer L. Dodge, *Chairman,* W. Otto Birk, J. W. Cell, R. C. Gibbs, H. P. Hammond, A. D. Moore, F. L. Wilkinson, Jr., W. R. Woolrich, H. O. Croft, *ex-officio,* C. A. Powel, representing Westinghouse Educational Foundation.

After the June meeting, Dean C. E. MacQuigg, the new president of the A.S.E.E., appointed Dean E. B. Norris of Virginia Polytechnic Institute and Professor H. E. Wessman of New York University to the committee, re-

placing Dean Hammond and Dean Wilkinson, whose terms of office expired.

It has been understood among members of the committee that an attempt would be made to secure continuity of policy by having infrequent changes in the chairmanship, with a year or two of overlapping service of the new and former chairman on the subcommittee. In accordance with this policy, Professor H. E. Wessman, one of the new members, has been made chairman.

Our two years of experience have brought me to the following conclusions with which I think most, and perhaps all, of the committee members agree.

1. An attempt should be made to select a recipient who is not much, if any, older than forty. This is in keeping with the intent of the plan for the award as approved by the donor.

2. This being the case, nominations must be heavily documented. Committee members cannot be expected to be familiar with the work of candidates from first-hand information. The committee must work largely from the material presented by the nominator and the supporters of the nomination, *supplemented* by the personal knowledge that it is to be hoped some member or members of the sub-committee may have.

3. Personal knowledge alone must not be depended upon, for it is fragmentary and may be prejudiced.

4. The chairman must be prepared to do a great deal of work in making certain that the nominators of the better candidates furnish all the material necessary for the proper functioning of the committee. Some nominators will not realize that inadequacy of supporting material will defeat even the best candidates.

5. It is generally agreed that the committee cannot, because of financial limitations, expect to meet as a whole except at the annual meeting. It should then devote itself largely to matters of policy.

6. An actual meeting of the subcommittee is essential to the success of the program, for much light is thrown upon the problem of selection by the discussion.

7. The chairman should bring to the sub-committee digests of all nomination material so that the choice can be reduced quickly to a half-dozen or so candidates and the time of the subcommittee devoted to a careful study of their full credentials.

8. The sub-committee may well indicate its preference for a particular nominee, but it should not do so to the point that committee members will not be free to vote otherwise. The subcommittee should, if possible, name more than one nominee for serious consideration by the general committee, but not more than three or four. The sub-committe should feel free to make brief comments with regard to its opinion of these candidates.

9. *All of the material* dealing with the nominees selected by the subcommittee should be sent to *all committee members*. A simple arrangement for doing this was worked out last year which operated quite well. The importance of sending each committee member all of the papers for each candidate who is to be seriously considered cannot be overestimated. It is only in this way that the committee members can participate effectively.

10. One of the most difficult tasks for the committee, and particularly the sub-committee, will continue to be to distinguish clearly between contributions to the *teaching* of engineering and contributions to the *science* of engineer-

ing. Contributions to teaching are so much more difficult to recognize that there is always danger of passing up the teacher in favor of the man who has made a name for himself as a specialist in some field of engineering. To do so would defeat the purpose of the award.

Financial Statement

Receipts

Westinghouse Educational Foundation for Award ($1000 cash) and expenses of Committee ($250) (Payment made June 24, 1947)	$1250.00	
Balance from Dec. 7, 1946, statement	33.51	
		$1283.51

Expenditures

Award	$1000.00	
Printing of announcements, etc.	45.00	
Certificate of Award	10.00	
Luncheon expense	10.50	
Postage, clerical expenses, committee expenses	155.92	
		$1221.42
Balance carried over		$ 62.09

Engineering Professional Status as Related to Labor Unions*

By J. F. DOWNIE SMITH

Dean of Engineering, Iowa State College

Before going into the subject we should first consider what is meant by an engineer and by a professional engineer. It may be your impression that the engineer is a professional man and is accepted everywhere as such. However, there is considerable question about it and I should like to elaborate. In the first place, according to C. E. Davies, Secretary of the American Society of Mechanical Engineers, in 1940 there were 245,700 persons in the United States of America, or about one in 570, who called themselves engineers. They participated in more than 300 so-called engineering organizations of national, state or local scope. Some of these societies are not limited to engineers, but are open to all those who have a legitimate interest in the subject. The man may be a salesman for the type of product developed by the engineers of that society; or he may be an administrator who likes to keep his eye on promising young engineers, and so on. The same year 62,235, or about *one-fourth* of the total, were registered by 45 states to practice engineering within those states' borders. In 1946 more than 76,000 engineers were registered.

There are 133 educational institutions in the United States which have one or more accredited curricula and which grant degrees in 17 branches of engineering. It is estimated by W. M. M. Boring that in 1948, 35,000 young people will be graduated with baccalaureate degrees in engineering; 1949, 43,000; in 1950, 51,000; and in 1951, 37,000.

Definition of Engineering

Now, engineering has been defined as "The art of organizing and directing men and controlling forces and materials of nature for the benefit of the human race." "The engineer's daily task is that of applying science in an economical manner to the needs of mankind. Engineering is a profession and the ideals that prompt a sense of professional responsibility will guide the man who enters it."

The Facts

That makes a pretty picture, but does it jibe with the facts? According to W. F. Ryan (1), of the Stone and Webster Engineering Company, some sixteen years ago Matthew Wohl of A. F. of L. told a group of Harvard engineers: "The trouble with you engineers is that you fancy yourselves as professional men. Actually you are just hired help." Ryan also states that "the majority of engineers are not em-

* Presented at the A.S.E.E., Engineering College Administrative Council, Washington, D. C., Nov. 12, 1947.

ployers. Most engineers are not definitely a part of management. There is only one alternative to classification as professional men—it is classification in the ranks of labor. Are engineers willing to accept this classification?"

Recently a student asked one of our faculty members, "When I graduate what union will I be entitled to join?" Is this unique?

Considering the fact that one of the engineer's prime responsibilities is organization, he has perhaps not been entirely wise in his handling of his professional activities and social contacts.

How can we tell an engineer when we meet one in industry? Clearly it cannot be because of graduation from a technical college, for many engineers of distinction never went to college. Indeed the best engineer I ever met probably did not get through high school. If you were to walk into an organization devoted to machine design activities it would be difficult to tell from the work being done which men had graduated from college and which had not. And what is the effect of this in the outside world? Let me illustrate by a few examples. In 1946 Mr. R. L. Forshay presented a paper before the American Society of Mechanical Engineers (2) entitled "Collective Bargaining for Professional Employees." I shall quote one or two passages from that paper.

"Let's look at some actual conditions, not simply theoretical or hypothetical situations. Let's take the case of the field engineering force on a construction job in Illinois where the A. F. of L. building trades are fully organized. This past spring the management of the engineering firm was advised by representatives of a labor union that these engineering employees, part of whom were professional engineers, should be members of a certain A. F. of L. technicians union which embraces such employees. The management apparently ignored the advice and failed to mention the incident to the employees affected. Some time later, the union made a direct contact to the men, advising them to join their union. Upon refusal, an A. F. of L. picket line was established around the job and work was stopped for two months. After some jockeying by both sides, work was resumed, but the union singled out two professional men and would not allow them entry to the project. The alternatives for these men seemed to be either to join the union or be forced out of their jobs. The only other recourse which they have under present labor laws is to form a collective bargaining group with employees having mutual interests, unless they may seek refuge under the recently enacted Hobbs Bill."

"The Southern California Professional Engineers' Association has been very successful in holding negotiations for collective bargaining contracts on a professional level. The Association has a contract signed in March of this year covering professional engineering employees at the Douglas Aircraft Company plants at El Segundo and Santa Monica. It represents the professional engineering employees of the Los Angeles Department of Water and Power in matters concerning employee relations. It won an election contest from the C. I. O. by an overwhelming majority for certification as bargaining agent for engineering employees of the Southern California Gas Company. In this particular case, the NLRB would not permit separation of the professional and sub-professional employees, holding that 'A unit delineated upon the basis of the scholastic (or equivalent) history of individual employees rather than on the basis of their function, would in our opinion be unworkable and inappropriate for collective bargaining purposes.'"

". . . Mr. William H. Davis, former Chairman of the NLRB, in a speech before the Metropolitan Section of A.S.C.E. in New York on November 15, 1944, pointed out that 'professional workers are in a difficult position between management and production workers. The theory that their position is an impartial one finds little support in actual practice. Their functions are sometimes managerial, and NLRB has quite generally recognized that their ethical and economic outlook is so different from that of production workers as to make separate bargaining groups for them a logical arrangement.'"

You will notice in those passages that pressure has been exerted upon engineers which has nothing whatever to do with technical training.

Organization of Engineers

It has been pointed out that in recent years strong pressure has been brought to bear upon engineers to join labor unions affiliated with the C.I.O. and the A. F. of L. Most engineers are rather opposed to such a move, and in order to combat it, many have formed bargaining units of technical employees. Once the engineer is in what amounts to a union he finds it extremely difficult to get out satisfactorily. In the past there has been very distinct justification for the creation of labor unions, and I believe that today the average person is in favor of such a movement. However, labor union leadership has not always been wise. For example, the city of Lynn, Massachusetts, used to be one of the foremost towns in the world devoted to the manufacture of shoes. The shoemakers were not well paid and worked under very poor conditions. This was a natural breeding ground for strife, and the industry was a logical place for the development of labor unions. When they did develop, they went much too far in their demands, and made life so difficult for the owners of the firms that almost every one of the factories closed up shop and moved elsewhere in the country. The effect on the shoemakers in Lynn, and on the city itself, was enormous. It is now coming back as a shoemaking center, and it is hoped that the unions have learned a lesson. At the moment it would seem as if we are going through similar procedures in other fields of endeavor; the owners, the management, and labor are all necessary for the proper operation of a business in this society which we have today. Andrew Carnegie was once asked which of the three branches, labor, capital, or brains, was most important, and he replied by asking which leg of a three-legged stool was most important. When one branch develops too much aggressiveness, the government may step in and regulate that particular branch, as it did with management and business in the early days of the New Deal, or may try to regulate labor, as it seems now to be in the process of doing. If the government, or industry itself, does not keep all three parts in proper balance, our system of business operation will fail.

It has also been stated (3) that:

"The man of average ability must decide whether his best interests will be served by membership in a union of engineers or in a larger and more powerful organization. In a union of engineers he may suffer because of a lack of bargaining strength, while in a larger labor group, his interests may be submerged by those of the far more numerous production workers. As a potential member of management, the engineer is naturally averse to union membership, but many engineers have been forced into an organization of their own as an alternative to being

forced into the broader type of organization just mentioned.

"For his own advancement, and for the good of the profession of which he is a member, the engineer needs to be a part of his professional group, and he needs it most at the beginning of his career. Furthermore, somewhere along the line there must be built in him a sense of concern, a social conscience, that will not be satisfied with personal success within the bounds of his profession, that will drive him on and out with our citizens to assume the responsibility for good government and to help in making secure our essential freedoms. If he would take a more active part in government and in human affairs, he would be less likely to be subjected to the unionization that has been forced by government during the last decade."

Professional Standards

An important fundamental question can be raised on this subject. Can we reconcile collective bargaining with professional standards? Some say yes, but most mature engineers with whom the author has had dealings say no. Call it what you will, such a unit is a union just as much as the coal miner's union is. Is this what the engineers want? I don't think so.

Now the other professions needn't look down their noses at the engineers. For example, in the field of College teaching there is the American Association of College Professors. No one thinks of that as a union, but in many respects it does just what unions do. For example, if a union decides that it doesn't like the working conditions in a plant it notifies the management, and, if nothing is done to improve conditions, the men may go out on strike. Isn't this quite similar to what happens when the College administration decides to do certain things not to the liking of the professors? If the case is strong enough, the professors are likely to blackball the school, which is much the same thing as calling a strike. You can recall, I feel sure, some actual cases of that sort.

The American Medical Society has also laid down certain minimum conditions to be accepted by others before doctors can be employed.

Yet, in spite of such cases, no one questions the fact that Teaching, Medicine, and Law are recognized professions!

Unfortunately, some engineers have been forced to accept conditions in labor contracts which seem to me not compatible with professional standards. For example, a contract has been accepted at the Stone and Webster Engineering Corporation of Boston which includes the following paragraphs.

"All decisions with respect to promotions shall be made by the employer. There shall be *no* promotions, however, to a higher classification within the bargaining group, while employees having greater seniority in the higher classification are on lay-off.

"When a lay-off takes place, top seniority will be accorded to not more than eight persons to be designated by the union *from their elected officers and stewards.* The employer will be kept furnished with a current list showing the persons designated."

Registration

Now many engineers have been registered to practice in the several States. What does this mean? It only means that the engineer has satisfied a State Board of Examiners that he is competent to practice engineering in that state. Arbitrary rules have been set up and each man is examined. It is customary to expect that the man would be a technical college graduate

with several years of practical experience back of him. This would be comparable with the requirements of the American Medical Association. But the professional engineer at present is not necessarily a technical graduate. A man can't be legislated out of a job, so in each State it was necessary to insert the so-called "Grandfather clause" to permit men who have been practising engineering successfully for years to continue.

The pressure to register is far greater in civil engineering than in some of the other fields, such as mechanical or electrical, for instance. Indeed, in mechanical engineering there is practically no necessity to become registered unless the man desires to practice as a consulting engineer. Why, then, are engineers in industry becoming interested in registration? There seems to be a feeling that registration may, in some undefined way, be an instrument to minimize pressure from union organizations, to improve the professional standing of the engineer, and perhaps to help him financially.

Let us look at the points individually.

(1) *Do we eliminate or minimize pressure from labor unions by registration?*

This point is not clear although unions in the past have treated registered professional engineers as hired help.

(2) *Do we improve the professional standing of the engineer?*

In some fields, yes. Probably fairly definitely in civil engineering. In other fields there seems to be no effect whatever from registration.

(3) *Do we help the engineer financially?*

The civil engineer probably benefits materially, on the average, by registration. On the other hand, an article which appeared in *Mechanical Engineering* for September 1947 indicated that at the 40-year experience level, the civil engineer is the lowest paid of all the recognized engineering branches although he started at the highest rate of them all. In some other fields the engineer probably gains nothing financially and loses his fees.

We have just learned of an engineer who started poor twenty years ago and has retired with the comfortable fortune of $50,000. This money was acquired through industry, economy, conscientious efforts to give full value, indomitable perserverance, and the death of an uncle who left the engineer $49,999.50.

One large Electric Manufacturing Company, I have been informed, is encouraging the registration of its engineers. The thinking back of it may be perfectly clear, but the publicly expressed reasons are mild and not too convincing. One reason given is that the registered professional engineer has a better standing in court. Considering how infrequently the average engineer goes to court, this reason is not awfully strong. The unexpressed reasons must be the deciding ones.

Attitude of Founder Societies

The Founder Societies have concerned themselves up until now largely with the technical aspects of engineering. But there are other phases which require concerted efforts; such items as proper working conditions, salaries, duties to the public, etc., cannot be ignored, and require the unified effort of large numbers of engineers.

Because of differences in viewpoint the Founder Societies have had difficulty reaching common ground on recommendations suitable for the engi-

neering profession, and their labors have been interesting, but actually not too helpful, to the young man. In addition, the discussions have been long drawn out and engineers are faced with problems which must be handled immediately.

The National Society of Professional Engineers

One society, the National Society of Professional Engineers, was founded to handle non-technical matters for the engineer. It has had a rapid growth, and is still expanding. One of the requirements for entry to that Society is a certificate of registration in a State as a licensed professional engineer.

The fact that many distinguished engineers might have difficulty passing a registration examination can be taken care of by the examining committee. But if such a man cannot become a registered engineer he could still have a registered assistant. It may interest you to know that in one State there has been expressed the thought that on public works projects all drawings should be signed by a registered professional engineer or the bids will not be considered.

Up to the present time the N.S.P.E. has apparently not sold itself to the average mechanical engineer, although many such engineers are members. Perhaps if more of the officers were appointed by the Founder Societies there would be a greater feeling of sympathy towards it than now exists.

The Layman's View of the Engineer

Now these are matters of personnel relations in industry; but what does the public think of the engineer?

In *Mechanical Engineering* for July, 1947, there is an article entitled: "Who Was Holley?" In it there is a description of the work done by that man. There is a weather-worn memorial to him erected in Washington Square in New York. On the column which supports a heroic bust of Holley are inscribed the words: "To Alexander Hyman Holley, foremost among those whose genius and energy established in America and improved throughout the world the manufacture of Bessemer Steel, this memorial is erected by engineers of two hemispheres."

Quoting the article: "Recently, a New York reporter, noting the apparent neglect of the monument, asked, 'who is this man?' No one in the park could tell him.

"One woman commented scornfully, 'How delightful to erect a statue to one that invented steel. Where I come from (England), they erect statues to philanthropists, and poets, and humanitarians. It's a sad commentary on American life.'

"Another said, 'I've read the inscription every time I pass, but I still don't know who he was. They ought to put a clock in his head so we'd know what time it is?'

"To engineers who cherish the memory of Holly, these words spoken in ignorance cut deeply, for they confirm what engineers regretfully acknowledge—that the story of American engineering has not been adequately told."

Conditions of Employment

These facts, all together, indicate that the engineer is not always looked upon as a professional man, nor are his accomplishments recognized by the public. Why? Perhaps the answer lies in the training and experience of the engineer.

In general, the engineer has worked

for someone else, who is more likely than not to get the credit for achievements of note; but this is unquestionably not the main reason. He seems to have an innate objection to self-advertising. He doesn't shout from the roof tops about his achievements. Indeed, even if he wanted to, he probably couldn't, for it is frequently company policy to prohibit the discussion of his work on the outside. This is understandable when we realize that he may be developing new products or processes, and leaks might help a competitor. In addition, the nature of his work is such that it is not readily understood by the layman; whereas, for example, in the field of law almost anyone can get the gist of the argument even although he can't see the legal technicalities. When a man is being tried for a particularly gruesome or salacious murder, the headlines in the papers are large and frequent, and the lawyers involved are often mentioned. But if their cases are built upon evidence gathered by an engineer or scientist what recognition does he get? Nothing comparable, although without his analysis the lawyer would be lost. This is not a disparagement of lawyers, but an indictment of the engineering profession. They are too self-effacing.

The Future, Professionally

In the first place engineers must put their own house in order or be relegated to a position inferior to the other professions. This, I am sure, will be done, although it is a long way off. Among the first steps seems to be to require registration of engineers in the several States, just as is required of medical doctors. After this has been largely accomplished (and already more than 35 per cent are registered), a unified engineering society should be established to do much as is now done by other professional societies.

But this, of course, is not enough. In order for the engineer to achieve public recognition he must take a much more active part in civic affairs. The Founder Societies are emphasizing this all the time, and so are many teachers of engineering subjects in Colleges. It seems to be bearing fruit slowly. Now engineers have a type of training which could help communities a great deal.

Their scientific viewpoint has been adopted at times even by the ministry. The *London Humorist* told that the Easterly wind had dried the land, and the crops were suffering from the drought, so the agriculturists of the parish waited on their Scottish minister with a request to "put up a word or two for rain." The minister, who had a reputation for the efficacy of his supplications on previous occasions, heard the deputation gravely, and, after a silence, during which he carefully scanned the horizon, replied: "A wull, but, A'll bide a wee till the win's mair off the West!"

The engineer should acquire a broader knowledge of conditions in other parts of the world, since many of the problems existing elsewhere are being handled in ways which might help us. Similarly, our way of doing business may help others. Recently, while talking to Dr. Rayford Logan, Professor of History at Howard University, he stated that he thought one of the best ways of improving conditions for native labor in the rubber plantations and tin mines, etc., was for them to form strong labor unions. They could probably learn something from us on that subject.

In Iowa we are considering the creation of a building code. Clearly

engineers and architects can help considerably in such work. The State is thus fortunate in having appointed as chairman of the Building Code Council a civil engineer, and as technical secretary, an architect—both on the staff of Iowa State College.

In community planning there is clearly a need for landscape architects, civil engineers, and traffic control specialists, who may, or may not, be civil engineers. Again in Ames the staff of the Iowa State College is actively supporting such work.

The same type of thing can be carried on in Federal affairs. In Congress, comparatively few representatives are engineers, yet many bills can best be handled by technically trained men. If the engineer really becomes civic minded perhaps that condition may be remedied.

Now engineers have been, in general, dealing with impersonal matters —such as the designing of machines. The results can be to a large extent predicted from scientific laws. But in the field of human affairs conditions are different. This has led many brilliant and competent engineers into difficulty. The engineer has to acquire a better knowledge of human behavior.

In addition to this broadening of his social activities, the engineer, of course, has to keep up with the technical aspects. At no time in history has change in technology been so rapid. You all know that in 1939 very few people considered atomic energy as anything more than a scientist's pipe dream. Yet in a very few years we became keenly aware of the realities, and appreciate the great progress made.

Perhaps we are considering that the engineering profession is a little sick. Let's hope it won't get to the same state as in the following story from the *London Evening Standard*.

A little boy was running madly along the street. A kindly old lady stopped him and said: "My dear little boy, where are you going so fast?" The little boy answered: "I'm running for a doctor; my grandpa's sick!"

"Now," replied the old lady, "you run right back to grandpa and tell him he only thinks he's sick."

A couple of days later, the kindly old lady saw the little boy in the street again. "My dear little boy," she said, "is your grandpa all right now?"

"Yes," replied the boy, "he's all right now. He thinks he's dead, and we are going to bury him next Sunday."

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Correlation of Unit Operations and Processes

By D. E. MACK

Professor of Chemical Engineering, Lehigh University

The subject of unit operations in the study of chemical engineering has, since its introduction, been hailed as one of the most important ideas ever conceived for the orderly study of a very complex subject. Indeed it has become the basic idea in all chemical engineering study, and emphasis on this phase seems to take precedence over all other aspects of the subject in most institutions. This emphasis should not be considered as a fault, however, since it is only proper.

The subject of unit processes or chemical changes as distinct from unit operations or physical changes, has not met with the same success. There are those who go so far as to say that the same type of general classification, when applied to chemical changes, has failed entirely in accomplishing the desired end, which is to put orderliness into the subject. Whether time, with further study and information, will serve to remedy this defect, we do not know, but we may as well admit that in its present state, the effectiveness of the unit processes concept leaves something to be desired.

Before attempting to show how we are trying to improve its effectiveness as a study tool in conjunction with Unit Operations, it is necessary to analyze briefly some of the difficulties encountered in teaching it as an entity apart from Unit Operations.

1. First of all it suffers from being largely descriptive in nature, each subclassification of the subject consisting of a mass of factual material. The necessary physiochemical information needed to correlate the facts is for the most part still unknown.

2. Secondly the equipment used for conducting chemical reactions is by no means standardized, as are, for instance, pumps of heat exchangers in the unit operations field.

3. Also, much technical data such as heats of reaction and other thermodynamic properties are still unknown, which makes the anticipation of energy requirements difficult and recourse must be taken to guessing when any change from an existing process is desired.

4. The most important difficulty and one from which unit operations likewise suffers is the fact that a great many changes involve both chemical and physical phenomena taking place at the same time, or in other words an operation and a process occurring simultaneously. The fact that a basic text in unit operations can be written without once introducing a chemical equation or a text in unit processes be written without a single reference to a film coefficient I believe shows a decided need for some kind of a course

* Presented at the Middle Atlantic Section meeting, New York, December 6, 1947.

wherein the interrelation of both concepts be studied. We are currently trying out a course of this kind at Lehigh University.

This has been attempted at other institutions in a course usually called "plant design," but such a course has its limitations also. Courses in "plant design" do, however, bring into the picture two other aspects; namely, materials of construction and equipment costs, which must necessarily enter into any practical consideration of unit operations and processes.

The course, which we are teaching in the undergraduate curriculum, has as its objective the putting together of unit processes and operations, together with consideration of materials of construction and equipment costs, with emphasis on the organization of the total picture rather than emphasis on any details, so that the students can develop judgment in ascertaining the relative importance of each part. It was felt that the best approach to such a coordinating course was to give the students the problem of designing several plants for the production of various chemicals with discussion each step of the way. Obviously, such a course was out of the question from a consideration of the time which would be required. We therefore tried to see if we could "whittle the idea down to size" so to speak and still retain its qualities.

A consideration of where the major amount of time is usually spent in a plant design project showed that most of it is consumed in searching the literature for information regarding the particular project and in performing the many and complex unit operations calculations required, such as for heat exchangers, stills, absorption columns and the like. It was felt that if the student could be given some "short-cut" methods for approximating the unit operations calculations that a major time saving could be achieved. This was done by preparing several tables of approximation methods. The students are made fully aware that the approximations are just that, and they are presumed to be equipped to perform the more exact calculations if needed. Besides saving time, this idea also gives the students a feeling for the "guesstimation" which is an essential part of any design. The approximations include tables of heat transfer coefficients for various situations, tables of absorption coefficients for various systems, approximate power equations, etc.

To save time in searching the literature, the work is divided throughout the class. Each student is given some phase of the work to look up and is required to bring the information to class in a form which can easily be assimilated by the rest of the students, such as a table, a graph or a calculation, with the proper references. Such items might be a vapor pressure curve, an equilibrium constant, an x-y diagram, a table of suitable construction materials, specifications for raw materials or products and the like.

With the unit operations approximations and the necessary data available, the students then have time to concentrate their mental activities on the integration of the entire problem, which is the objective of the course. After an orientation period where the problem is explained, the data accumulated and a tentative process outlined, the class periods consist of a systematic attack on the various phases of the problem. At this point the general principles of the "Unit" changes are

clearly demonstrated as the various possibilities for accomplishing the desired end are discussed.

Most of the work is done by directed recitation. Several methods for performing each part of the process are usually considered and the best one decided upon. Calculations are roughed out and left for the individual students to complete.

Where data is lacking, "reasonable assumptions" are made. This part is food for much argument in class between students and goes a long way toward eminating the feeling inadequacy on the part of the men when they find themselves confronted by lack of method or facts to surmount a technical problem. They are usually surprised to find that common sense and non-technical knowledge can overcome many difficulties. They are forced to become aware of their surroundings, such as the quality, temperature and pressure of city water, or the cost of electrical current, water, steam and gas. In the work they have had to use a great many very earthy facts. To guess at how long it would take a tank to fill and drain a tank we had to resort to our memories of how long it takes to fill and drain a bathtub. To approximate the time required to shovel tan-bark into a reactor we called on our snow shoveling memories. To determine the time of settling of a mud-like slurry we brought in a glass of muddy water and watched it. We decided that water pump grease would lubricate a pump operating on dilute alcohol because it does so in an automobile radiator. Here are a few questions to test your own knowledge of your surroundings. About what screen mesh will pass "regular grind" coffee? What is the calorific content of the gas your wife uses to cook with? How many gallons per minute does your water tap deliver when operating wide open? How many tons of mercury could you put in your garbage can? As trivial and perhaps humorous as these questions may seem, they serve to illustrate the type of information which must be used to fill up the gaps in the facts ordinarily available to students.

After several lectures concerning the various parts of the process, it is put together and balanced stoichiometrically. The equipment is then roughed out for size and cost and those parts which are of major importance, economically speaking, are considered with more care and more exact calculations are therefore made.

When the process has been completed in lecture, the student has rather voluminous notes sufficient to allow him to effect the superficial design of a process without having to make extensive calculations or literature searches, and with all the gaps filled in by one means or another. He then makes his own design and presents the results in the form of a report which includes among other things, a stoichiometric balance, a flow diagram, an estimation of the size and performance of each major piece of equipment, an estimation of costs, and an operating procedure. The students then exchange reports and each student prepares a written criticism of the work of some one else, not only a technical criticism but criticism of the report itself for clarity, grammar, punctuation, spelling and the like. The reports are then collected and graded.

We find that about five processes can be covered in a one semester three-hour course so long as we select simple processes. Some of these have been:

Chlorination of benzene
Manufacture of dibutyl phthalate from butyl alcohol and phthalic anhydride
Extraction of gall nuts (For this one we obtained all our data from a Chinese student who had done considerable research on the subject)
Manufacture of ammonium sulfate from ammonia and sulfuric acid.

It can be seen that many small points not covered in the more specialized courses must be taken into account in this course since entire processes are being considered. There is no such a thing as saying that something will be "covered later" or is "beyond the scope of the course." No student is allowed to say "no information is available." We attempt to utilize the student's entire training and if the subject becomes too complex for his state of knowledge he has to stagger through it some how.

In the working out of the final plan of the process, collaboration between students is not only expected, but desirable, not only to eliminate much of the tediousness of the work but to bring about discussions on those points where judgment and common sense are required.

The students are requested not to collaborate on the actual writing of the report, and to date no evidence of duplication in this respect has been found.

Improvement in reasoning power, organization, and composition as the course proceeds are remarkable. The first report from each student is usually quite a monstrosity, but it is considered acceptable if the process might possibly work, regardless of the inefficiency, awkwardness or poor design of the equipment. By the time the course is finished, it is expected that the design will not only be reasonable, logical and efficient, but that the report itself will be well organized, clear and concise. In the first part of the course, emphasis is necessarily placed on the technical content. In the latter part, the emphasis is placed on the composition of the report.

The final examination, which is done in a regular three-hour examination period, is the solution of a very simple problem with elementary technical matter. The grade is given almost entirely on the organization and presentation of the answer rather than its actual solution.

It is felt that the course is accomplishing its purpose. It requires the use of most of the technical courses, and all the English courses, that the students have ever studied. At first they feel very frustrated, but as time goes on they begin to feel their own power and take considerable pride in their work.

The course has certain disadvantages as far as teaching is concerned. The reports take a long time to grade properly, since each one must be carefully studied and criticized. Many of the reports must be criticized in conference with the student. However, the resulting enthusiasm and mental growth of the students more than repays for the extra effort.

Engineers at Work—the Du Pont Engineering Department*

By G. M. READ

Chief Engineer, E. I. du Pont de Nemours & Company

Educators are charged with a great responsibility because they indoctrinate thousands of young men and women with their future philosophy of life. The college training of our young engineers will profoundly influence our future economy and will be a cornerstone in the new era which lies immediately ahead.

An understanding among the colleges and schools of the circumstances that confront the young engineer when he begins his career in industry is necessary. A description of the part played by the engineer in a typical large industrial organization should be helpful in promoting such an understanding.

The industry with which the writer is associated is basically a chemical manufacturer and produces a wide range of chemical products. The Company is organized through ten industrial or manufacturing departments and fourteen auxiliary departments and divisions. The ten industrial departments have their respective general managers. The auxiliary departments provide various specialized services required by the manufacturing organizations.

The industrial department as a whole functions very much the same as an independent manufacturing organization of equal size. The industrial department receives specialized services of various kinds from the several auxiliary departments. In addition to the services of the auxiliary departments, the general manager of the industrial department receives guidance on broad policy matters from an advisor who is a vice-president and a member of the Company's Executive Committee. The general managers of the industrial departments and the directors of the auxiliary departments report directly to the President of the Company. To all intents and purposes the general manager is solely responsible for the functioning of his department. He is, however, limited as to capital or other unusual expenditures. Such expenditures are handled as individual projects, and those involving expenditure above a predetermined amount must be submitted to the Company's Executive Committee for approval.

Th actual number of products manufactured by this industrial organization runs into the thousands. There are ten manufacturing departments which specialize in related groups of products.

The Ammonia Department specializes in high-pressure synthesis, its

* Address delivered before Middle Atlantic Section of A.S.E.E., December, 1946.

products including methanol, ammonia and nylon intermediates.

The Electrochemicals Department specializes in the products of electrolysis of common salt.

The Explosives Department makes nitrocellulose and related products such as dynamite.

The F. & F. Department makes protective coatings such as paints and coated fabrics.

The Grasselli Chemicals Department makes inorganic acids, salts, and insecticides.

The Organic Chemicals Department produces complex organic compounds ranging from dyes to "Freon" fluorinated refrigerants.

The Photo Products Department produces photographic films and sensitized paper.

The Pigments Department makes paint pigments in great variety.

The Plastics Department prepares a wide range of plastics in the forms required by industry.

Last, but not least, the Rayon Department makes rayon, nylon and cellophane.

The Engineering Department of this industrial organization is one of the auxiliary departments, which employs some 2000 salaried workers of whom about 900 are graduate engineers. It does almost all the major project engineering for the industrial departments. Its work centers in the main office of the Company.

The centralizing of engineering work in the main office of the Company is the result of study and experience over a considerable period of years. Some of the underlying resasons are of interest.

Expected expenditure for construction for the next several years amounts to many millions of dollars. A program of this size presents numerous highly specialized engineering problems, such as distillation, absorption, drying filtration, agitation, water purification and filtration, fume and dust handling, stream and air pollution, heat balances, materials handling, fluid flow, and materials of construction. It is readily understandable that, by pooling technical knowledge at one central location, the duplication of technical effort can be held to a minimum, and there are a sufficient number of specialized engineering problems to employ gainfully a well-rounded-out group of engineers with a broad knowledge in various specialized engineering fields.

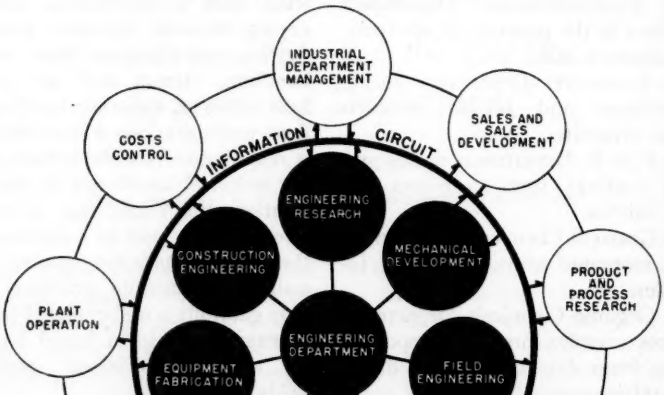
An important economic consideration is the speed with which a new product can be introduced on the market. The rapidity with which this can be acomplished depends to a considerable degree on innumerable engineering and chemical factors. Briefly, some of these are:

1. Chemical and physical considerations affecting the choice of materials of construction.
2. Economic factors, such as raw materials, purity, quality, yield, waste, and by-products.
3. Plant location or site selection and economic analysis.
4. Design and construction.
5. Time schedules.

All of the above-mentioned factors must be coordinated into one master schedule which must be strictly adhered to if the product is to be produced according to sales requirements.

To design and construct a chemical plant today requires broad engineering experience in many specialized fields. Based on years of experience, this industrial organization has centralized

RELATIONSHIPS BETWEEN AN ENGINEERING DEPARTMENT AND A MANUFACTURING ORGANIZATION



its engineering know-how. Irrespective of the versatility of any one small plant engineering group, it could cover but a small portion of the vast and rapidly changing technological fields. It would be a great waste of time and money to have in a single large company individual engineering groups at various plant sites endeavoring to encompass all phases of engineering.

As illustrated in Exhibit, 1 every industrial department has a production group with a plant manager and his staff at each of several plants. It has a sales director with a sales organization which more or less covers the United States. Sales and production groups are served by a comptroller's organization and a technical organization.

The central Engineering Department has five major functional divisions, namely, the Design Division, the Accounting and Estimating Division, and Construction Division, the Industrial and Development Engineering Divisions, and the Wilmington Shops. These divisions offer a variety of specialized services to the various components of the Company.

The Design Division is responsible for the design and specifications for new plant buildings, for the selection or design of equipment, and for major

alterations to manufacturing facilities, services, and utilities.

The Construction Division supervises in general the construction activity of the Company and directs the more important construction work.

The Industrial and Development Engineering Divisions embrace groups whose objectives include engineering research and aid to the industrial departments and others in development, evaluation, and selection of most suitable processes and equipment, and securing the most effective use of facilities and personnel.

The Wilmington Shops comprise foundry, millwright, pattern, and machine shops in Wilmington for manufacturing special equipment and machines used by the various industrial departments.

Consider a few specific examples of the way the Engineering Department serves the industrial and other departments.

Suppose the piston of a big vacuum pump cracks unexpectedly and must be replaced immediately to keep the plant running. The Wilmington Shops can, if necessary, quickly cast and machine a new piston. It has the foundry and the heavy machine tools required for the work as well as the necessary skilled workmen. No single plant could afford to keep these facilities in readiness.

Suppose, again, that the manufacturing cost of blasting caps is slightly higher than desired, and it is decided to develop a new type of cap. The Industrial and Development Engineering group is called in to study the manufacturing cost of the present cap. In cooperation with the technical men of the industrial department, they work out a variety of possibilities for improvement. When the sales organization of the industrial department is satisfied that the new design recommended will meet the needs of their customers and that the proposal is economically sound, a project is prepared to proceed with the development of equipment. Equipment development is a matter of cooperation between plant personnel and the Engineering Department.

Suppose, for example, that the technical director of an industrial department convinces his general manager that a new product under development is ready to be put on the market. He may then ask the appropriate plant Industrial and Development Engineering group to cooperate in estimating production cost and in preparing engineering information for the Design Division. The Design Division then works out the preliminary or final plans which the Estimating Section uses to estimate the cost of the manufacturing plant. The Engineering Department helps the industrial department prepare a project which is submitted to the Company's Executive Committee and Finance Committee. Authorization by the Finance Committee is authority for the Engineering Department to build the plant.

Perhaps it is found that some of the process steps in the new plant involve physical conditions or the handling of corrosive materials beyond available engineering data. Then the Engineering Research group may be called upon to fill in the gaps so that the design of the plant can be accomplished without too large a factor of safety and without unnecessarily expensive types of construction.

Actual engineering for an industrial organization of this size is a matter of close teamwork between large groups of men in the manufacturing organiza-

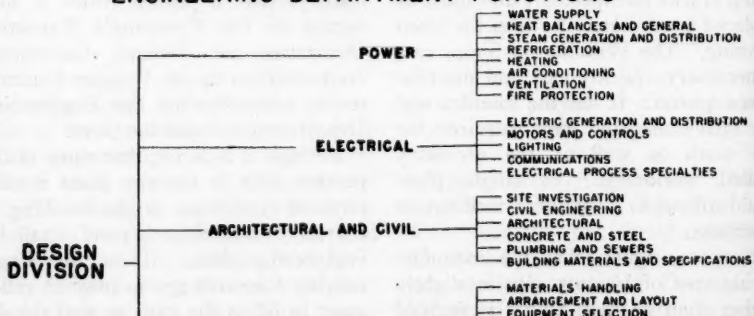
tion and large groups of men in the engineering organization. Each individual who has a contribution to make feeds his thoughts and experience into the "information circuit." Each engineer who has a job to do draws from the "information circuit" to make sure that he is taking full advantage of the entire fund of knowledge and experience possessed by the Company. By striving towards this ideal we create plants that are a real contribution towards lower costs to the consuming public.

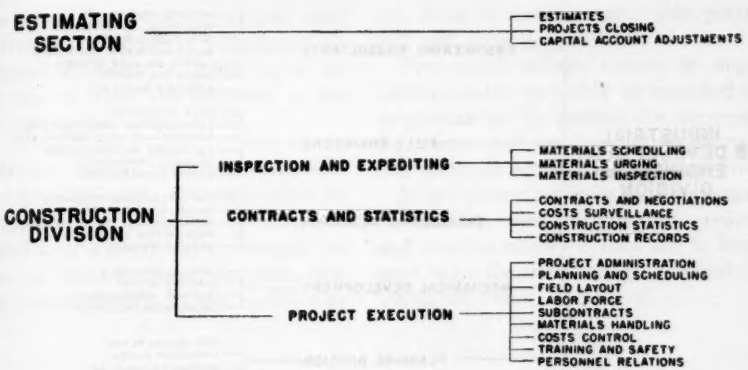
It is thus evident that engineering in a large organization is a very complex matter. It lends itself to a high degree of functionalizing, which is indeed an absolute necessity. Consider the significance of this functionalizing to the educators who are training the engineers that industry will use tomorrow to fill these various functions.

This particular industrial organization employs almost 3000 graduate engineers of which one-third are in the Engineering Department. In general, engineers are hired on graduation from college and every effort is made to make it worth their while to stay with the organization until they retire. Insofar as practical, engineers are trained, first, in the field groups of the Industrial Engineering Division, or as designers in the Design Division. They thus obtain intimate knowledge of the practical aspects of manufacturing operations. Depending on individual aptitudes and inclinations, some of these men graduate into other parts of the Industrial and Development Engineering Divisions or into Design or Construction Engineering work.

Over the years, the design and construction of new plants has been cyclic in nature with very pronounced peaks. There is accordingly a periodic flow of engineers between the various divisions

ENGINEERING DEPARTMENT FUNCTIONS





to meet the needs of the moment. There is also a very sizable flow of engineers between the Engineering Department and other departments of the Company, and many engineers hold top positions in the management of the Company.

Engineering work for industry today is enormously complex. This complexity has been recognized to some extent by the universities in setting up separate courses for chemical, civil, electrical, and mechanical engineers, to name but a few. These sub-divisions are nowhere near fine enough for the large industrial organization. Engineers in such organizations must have expert knowledge of their particular field so that the plants they plan can make products at prices that make them available to the mass market.

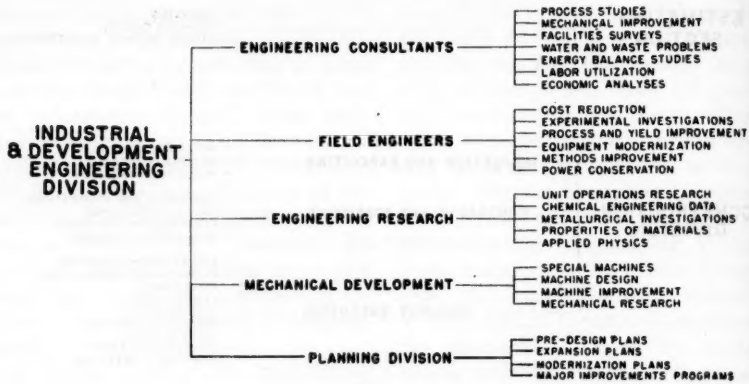
Let's examine the functional specialization that has proved practical for our particular type of industry.

Consider, for example, design project managers who are responsible for understanding the requirements of the job. They are responsible for seeing that the job progresses according to schedule through the Design Division. They are the contact men and coordinators of the work. An attempt has been made to place upon these individuals the further responsibility for knowing enough about the entire field of engineering and the Company's engineering knowledge and experience to judge who within the Company should be called in to help on any specific problem.

The actual engineering work of the Design Division is handled by functional specialists. These men are expected to be experts in their own particular fields. These men must make sure that for each project their special kind of engineering receives thoroughly competent attention.

The functions of the Design Division are indicated in Exhibit 2. Exhibit 3 shows, in like manner, the functions of the Estimating Section and the Construction Division. Exhibit 4 shows the Industrial and Development Engineering Division.

The method of handling engineering work, indicated in these diagrams, has been developed over a considerable period of years and has proved itself. The war period just ended was the most extreme test of centralized



engineering that could be imagined. This particular Engineering Department built fifty-four plants for the Government at thirty-two locations. The cost of building these plants was well over one billion dollars. The Hanford Engineer Works cost $350,000,000. At one time as many as 45,000 construction workers were engaged.

The design and construction of Hanford Engineer Works presented problems never faced before in history. There were no precedents, no guide posts. The project called for a type of ingenuity and mechanical developments which could take the findings of the nuclear physicists and translate them into terms of a finished product. New equipment, mechanical contrivances, and new automatic controls had to be invented on the spot, all within the limits of a rigid schedule.

The engineering specialization and cooperation that made Hanford possible can be equally useful in meeting the many problems of the years ahead.

American educators have done a wonderful job in training young engineers so that they fit smoothly into a functional organization like ours. They deserve a very large share of the credit for the outstanding accomplishment of technical men during the war.

However proud we may be of our accomplishments, this is no time to sit back and relax. We as a nation have obtained in the past six years an entirely new concept of our potentialities. We now face the problem of applying these potentialities constructively rather than for the purpose of destruction.

Industries demands on an engineering graduate may be summed up as follows:

1. The engineering graduate should be firmly grounded in the fundamental laws of science. Wherever he goes and whatever he does, his work must be in accordance with these laws.

2. The engineer must be able to get along with people. All engineering accomplishment is the result of cooperation—cooperation between engineers and other technical men,—and cooperation with those who carry out the plans that the engineer develops.

3. Last, but not least, the engineer must have the inherent ability to visu-

alize things that do not exist and must be trained habitually to compare alternative schemes for achieving a result, and to select the best way to the desired result.

Men are needed who will systematically develop many different ways to solve each major problem. Men are needed who will critically examine the merit of each possible solution that they have visualized. Only in this way can there be any assurance that plants will not soon be obsolete.

The usual college course in engineering could profitably be modified to emphasize to the student the necessity for vision and for comparing alternative methods of reaching an objective.

It is a prime requisite that engineers be imbued with imagination, vision, and creative ability if they are to keep pace with the ever-changing world in which we live.

College Notes

The College of Engineering of the **University of Michigan** is offering a symposium on "Dynamics of Stress and Strain," conducted by the Department of Engineering Mechanics. This symposium will consist of regular course work and numerous seminars and special lectures. The courses, seminars, and lectures will treat the following subjects: dynamics of machines and structures, elasticity, plasticity, creep, fatigue, metallurgy of engineering materials, and their engineering applications.

Courses will include the theory of plasticity, advanced airplane structures, and other special lectures given by visiting Professors John E. Dorn, David J. Perry, J. P. Den Hartog, N. M. Newmark, D. B. Steinman, C. R. Souderberg, as well as by Professors J. Ormondroyd and J. Freeman of the University of Michigan.

A fully-equipped German Diesel engine research laboratory, valued at more than one million dollars, will shortly be transplanted to the compus of **Oklahoma Agricultural and Mechanical College** it was announced by John W. Studebaker, Commissioner of Education, Federal Security Agency. Location of the former Klockner-Humboldt-Deutz laboratory at Stillwater will provide that institution with one of the two largest Diesel engine research centers in the United States. With allocation of the laboratory, President Harry G. Bennett of Oklahoma A and M announced establishment of the Oklahoma Institute of Technology, replacing the Division of Engineering of the College.

Teaching the Unit Process Laboratory*

By CHARLES J. MARSEL

Department of Chemical Engineering, New York University

The first paper which you have heard has dealt with the correlation of Unit Operations and Unit Processes. Just as the Unit Operations Laboratory is an integral essential for the teaching of Unit Operations, so a course in Unit Processes should be accompanied by a pilot-scale laboratory. Since Unit Processes laboratories are not common in Universities, and those in existence vary widely as to type, it was felt that a discussion of this phase of the course would be of interest.

Unit Processes were taught at New York University first in 1940. At that time the course was presented by an organic Chemistry professor from the Chemistry Department. The textbook was P. H. Groggin's "Unit Processes in Organic Synthesis," and little supplementary information of an industrial nature was presented; indeed, those Unit Processes dear to the heart of the classical organic chemist, such as the Friedel-Crafts reaction, were the ones stressed. The course consisted of two hours of lecture and one-three hour laboratory per week. Laboratory experiments were all conducted in glassware, and in essence were a repetition and extension of general organic experiments, such as the preparation of nitrobenzene, sulfonation of benzene, and a diazotization reaction. Naturally such experiments revealed little information to the students concerning the engineering aspects of such reactions when conducted commercially on a large scale. The author had additional contact at Purdue University where R. Norris Shreve, for many years chairman of the Unit Processes Symposia conducted by the A.C.S., has an excellent laboratory with large scale equipment; here, however, the laboratory course is essentially a graduate one, open to senior undergraduates as an elective.

Since it is desirable for undergraduates to acquire a working knowledge of organic technology, the course now given at New York University has this aim in mind. The principal Unit Processes are represented by experiments which are carried out, as far as possible, on a pilot-plant scale, in equipment duplicating that used industrially. This procedure is an ideal one, toward which all Unit Processes laboratory courses should strive. A brief listing of some of the experiments now in use or contemplated for future installation should be of interest. They include:

The nitration of benzene with mixed acids, in a steel nitrator, based on the commercial Hough nitrator.

Reduction of nitrobenzene to aniline, in cast iron reducer, using iron filings and acid.

* Presented at the Middle Atlantic Section meeting, December 6, 1947.

Sulfonation of benzene to form benzene sulfonic acid, and subsequent caustic fusion to produce phenol.

Low pressure hydrogenation of styrene to ethyl benzene at room temperature, using a Raney Nickel catalyst.

Oxidation of napthalene to phthalic anhydride.

High pressure, high temperature alkaline hydrolysis of chlorobenzene to produce phenol; reaction carried out in steel autoclave, with rocking as agitation.

Preparation of ethyl acetate in copper equipment.

Simple polymerization with possible processing of polymer obtained.

Chlorination of ethanol to yield chloral, and subsequent reaction with chlorobenzene to give the condensation product D.D.T.

The last experiment is of particular interest to the students, since they are allowed, at the conclusion of the work, to divide the product equally among all members of the squad. Several students have indicated that they found considerable use for the D.D.T., and one confided that his parents had been very proud to observe a tangible result of their son's engineering education.

It is clear that the above-listed experiments are designed to give the students a working knowledge of organic technology. However, there is one shortcoming which a program of this sort has; namely, that the complete sequence of operations has already been mapped-out for the students. There is no opportunity for original thinking or initiative, qualities which should be developed in the student at every opportunity. Therefore it was felt desirable to assign to the class, in addition to the outlined experiments, an original problem in organic technology. This need not be a difficult problem, but should preferably be of the type the young engineer might meet on a job involving chemical engineering research and development. It must be noted that an increased number of chemical engineers are yearly finding their way into research and development; the National Roster (1946) indicated 30.6 per cent of all chemical engineers were engaged in the field of research and development (1).

A typical original problem given to the Unit Process laboratory was the evaluation of variables and procedure in the manufacture of the new herbicide "2,4-D." This compound, 2,4-dichlorophenoxyacetic acid, has received considerable prominence because of its extreme effectiveness as a weed-killer against certain types of broad leaved plants. It is being produced commercially by three large chemical concerns, yet no details concerning its manufacture have been published. The only reference concerning its preparation is the original note in the *Journal of the American Chemical Society* (2), which reads as follows:

"Equimolar quantities of 2,4-dichlorophenol (5.0 gm.) and monochloracetic acid, (2.9 gms.) were heated with a slight excess of NaOH (2.7 gms.) and 15 cc. of water, until the solution was evaporated almost to dryness. The residue was then dissolved in 100 cc. of hot water, the solution cooled to room temperature, and acidified with HCl. A heavy oil separated, which soon crystallized. The mixture was extracted with ether, the ether extract washed with water and evaporated to dryness on a water bath. The yield of 2,4-dichlorophenoyxacetic acid was 5.9 gm. (87%); recrystallized from benzene, m.p. 138°;

white odorless crystals almost insoluble in water."

It must be admitted that one would have difficulty setting up a commercial flow sheet based on this information.

The problem was broken down into the following projects, which were assigned to small groups in the laboratory:

1. A study of the solubilities of all reactants in a number of solvents.
2. Analysis of solubility and other data to determine best method of separating "2,4-D" from reaction mixture.
3. A study of the possibility of preparing one of the raw materials, 2,4-dichlorophenol, by direct chlorination of phenol.
4. Analysis of the effect of the following variables upon the yield:

a. Temperature
b. Time
c. Excess chloroacetic acid
d. Agitation
e. Concentration of reaction mixture

5. Preparation of pilot plant batch of "2,4-D."
6. Fields of usefulness and methods of applying "2,4-D."

After working out all phases of the problem, a large batch was run in a 5-gallon Pfaudler glass-lined autoclave which was obtained for this purpose. An effort is being made to have the entire results of the project published. An important corollary was the extreme interest of the students in working on a certain phase of this problem, and then see their results integrated into an overall solution resulting in the successful preparation of a large batch of the product.

One may therefore conclude that the Unit Processes laboratory is best taught by pilot plant experiments simulating commercial operations, and the assignment of original problems to develop initiative and thinking.

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Design Stress Factors

By JOSEPH P. VIDOSIC

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General

A machine must be designed for many characteristics. Among these the more important ones are:

1. Function
2. Strength
3. Rigidity
4. Durability
5. Appearance

The first step is of course inevitable. If a certain task is to be performed mechanically, the system of mechanisms that will carry out the required function must be devised—the machine must be created or "invented." This probably consists of a skeleton outline depicting the linkage, gears, cams, springs, shafts, etc. that in combination are capable of producing desired relative motions, developing needed mechanical advantages and converting forces into work at one point or another. Having decided the scheme of action each part must then be proportioned for strength. All of the principles and theories of advanced as well as elementary mechanics stand ready to assist the engineer at this stage of the design.

The rigidity of the part must often be investigated next. If too flexible for the purpose, the part must be assigned greater dimensions and reapportioned. If too rigid, a condition which may arise particularly in cases of repetitive loads, material must be subtracted where it will least reduce the overall strength.

High speed parts develop forces which must be considered in the design. This is often the appropriate place to take these dynamic loads into account since the mass of each part can be readily evaluated. Strengthening of the part may be required to safely handle these added acceleration forces.

To assure a sufficient life for a machine part the designer must consider durability. Although much can often be done to keep wear at a minimum by designing bearing surfaces and other points susceptible to much wear so as to reduce friction, dissipate heat and eliminate unnecessary abrasion, durability should always be a deciding factor in the selection of the material for the part.

Finally it must be noted that in a market as highly competitive as ours the design can well be dictated by appearance, especially in consumer items such as the washing machine, the automobile or the air conditioning unit. Of course this does not mean that strength is neglected but rather that aesthetic features are added after strength has been accounted for.

Strength therefore is always the all important step in all designs. Consequently it is the purpose of this article to discuss the factors involved in the design for strength.

Selection of Material

The selection of a suitable material for a machine part is a most difficult task. Much must be known about the properties of all engineering materials —mechanical, physical, technological and chemical properties. It must be strong enough to transmit the loads. It must be tough enough to withstand environmental changes. It must be soft enough to be machinable or forgeable or weldable. It must be inert enough to resist corrosion. In short the designer must match the life requirements of the part to the expected performance of a material as indicated by its properties. When he discovers a material which promises to best satisfy the life requirements, he has made the appropriate selection. In doing this he should have answered the following questions to his full satisfaction.

1. Will the material satisfy the strength requirements?
2. Is the material capable of being manufactured into the part?
3. Will the part, made of this material, be capable of performing its task during the expected life in the environment in which it may have to function?
4. Will the material be available in sufficient quantity when needed?
5. Is the cost of making the part from this material as low as that of any other material that also satisfies all of the important requirements?

The properties which must be studied and with which a designer must familiarize himself, if he is to answer the above questions confidently, are listed below.

Mechanical Properties

Ultimate strength
Yield strength
Modulus of elasticity
Compressive strength
Shear strength
Shear modulus
Bearing strength
Poisson's ratio
Percent elongation
Hardness number
Impact strength
Fatigue strength
Notch sensitivity
Anisotropy

Physical Properties

Specific strength
Thermal expansion
Heat fatigue
Creep characteristics
Age hardening
Strain hardening
Electrical conductivity
Stress corrosion
Rate of shrinkage
Specific heat
Plasticity
Melting point
Absorptivity

Technological Properties

Machining
Casting
Forging
Swaging
Forming
Drawing

Chemical Properties

Composition
Chemical affinity
Microscopic structure
Weldability
Brazing
Surface treatment
Paint adhesion
Heat treatment

Stress

The maximum computed unit stress which is allowed in a machine part made of a certain material is the design stress. This design stress is sometimes called the working stress or the allowable stress. In order to prevent confusion it should be noted however that often the terms "working" and "allowable" are not used to indicate synonymous stresses. In such cases the phrase "allowable stress" signifies the stress to which the part could be subjected under totally ideal conditions. It thus becomes the yield strength or endurance limit of the material under the kind of stress that is to cause failure. The working stress, on the other hand, is the stress used in actual design of a machine part. The working stress takes into account the unknowns that are always present in practical design.

It has just been implied that the failure-causing stress is the theoretically allowable one and that this stress must be reduced to a "safe" value in order to obtain some margin of safety. The ratio of the theoretically allowable stress to the reduced "safe" stress is the real factor of safety. Thus when the failure-causing stress is divided by the factor of safety the design stress is obtained.

Consequently two critical items are involved in the determination of an appropriate design stress. The first is the failure-causing stress, the second the factor of safety.

Theories of Failure

In order to establish the failure-causing stress the exact mode of fracture or inelastic action should be known. Several theories which attempt to explain the condition developed in a stressed material that starts inelastic action and therefore results in failure have been proposed. Those that have gained recognition are:

1. The maximum normal stress or Rankine's theory.
2. The maximum shearing stress or Guest's theory.
3. The maximum strain or St. Venant's theory.
4. The maximum strain-energy theory.

The maximum normal stress theory claims that inelastic action begins when the maximum tensile stress acting at a point reaches a value equal to the tensile elastic limit of the material. The maximum shearing stress theory states that inelastic action begins when the maximum shear developed at a point approaches the shearing elastic limit of the material. The maximum strain theory assumes that failure begins when the maximum unit strain reaches a magnitude corresponding to the strain that occurs in a tension test at the instant the elastic limit stress is applied. The maximum strain-energy theory proposes that inelastic action begins when the energy absorbed corresponds to that that would be contained in a tensile bar of the same volume at the instant the stress reaches the tensile elastic limit.

It is thus observed that each theory assumes different causes for failure. Obviously each cannot explain a single fracture. Indeed this is not the attempt at all for one theory is found to apply better in one case than in another. For instance, in ductile metals the shearing stress seems to determine inelastic action, while brittle materials seem to be better explained by way of the maximum strain theory.

The matter of determining the exact cause of failure is therefore difficult

and at best uncertain. The theories are true only statistically. Consequently it is necessary to design so as to prevent the stress from exceeding some preestablished percentage of the elastic limit in the kind of stress that is principally acting. The establishment of an appropriate design stress therefore reduces itself to a matter of yield strength in the kind of primary stress acting divided by a suitable factor of safety.

Factors of Safety

The selection of a suitable factor of safety is an important and critical matter. This factor is sometimes appropriately called a factor of ignorance. After all, it is ignorance of many factors involved in the action of materials and loads that necessitates its use. Indeed its value gradually decreases as we learn more and more and as we better understand the uncertainties.

An enumeration of the unknowns and of the uncertainties that must be considered in arriving at a suitable factor of safety includes the following.

1. The degree of uncertainty of the magnitude and kind of applied load.
2. The degree of reliability of the material.
3. The extent to which assumptions must be made in the analysis for nominal stress.
4. The extent to which localized stress may be developed.
5. The kind of environment to which the machine may be subjected.
6. The extent to which human life may be endangered by failure of the machine.
7. The uncertainty as to the exact cause of failure.
8. The extent to which properties of the material may be altered during service.
9. The extent to which initial stresses may be set up during fabrication.
10. The uncertainty as to the appropriateness of using the material properties measured on a test specimen of one size in designing a part of another size.

Each of the above must be carefully considered and evaluated when deciding upon the factor of safety to use. Whenever exact facts concerning any of the uncertainties can be established, the effects can be separately accounted for. Much work has been done, for instance, to learn of the effect of size of part as compared to size of test specimen used to determine the material properties. Size coefficients can thus often be used to safely take care of this variable. Localized stresses resulting from contour discontinuities cause stress concentrations which can be provided for in many instances by the use of stress concentration factors (form stress factor corrected for the index of sensitivity). Furthermore minute surface roughness and environmental influences such as corrosion can be accounted for through surface coefficients. When existing conditions do not exactly correspond to investigated or otherwise known cases the possibility of undue stress must be guarded against by use of large factors of safety.

The evaluation of the effect of many of the uncertainties remains, however, to be almost entirely a matter for the experienced designer to handle. Experience with the material under consideration as well as with the design, operation and maintenance of a par-

ticular type of equipment cannot be replaced. The beginner must therefore supplement the lack of personal experience by reviewing practices that have been accepted because of the knowledge of those who have proposed and used them.

Commonly used factors of safety in basic design based upon the elastic limit fall within the range of 1.25 to 4. When commercially available elements are incorporated into the design larger factors are used for these in cases where their manufacture cannot or is not critically controlled. Such cases are becoming the exception rather than the rule. In normal design, factors of safety are usually taken according to the schedule that follows.

1. $n = 1.25$ to 1.5 for exceptionally reliable materials used under controllable conditions and subjected to loads and stresses that can be determined with certainty. Used almost invariably where low weight is a particularly important consideration.
2. $n = 1.5$ to 2 for well-known materials under reasonably constant environmental conditions, subjected to loads and stresses that can be determined readily.
3. $n = 2$ to 2.5 for average materials operated in ordinary environments and subjected to loads and stresses that can be determined.
4. $n = 2.5$ to 3 for less tried as well as brittle materials under average conditions of environment, load and stress.
5. $n = 3$ to 4 for untried materials used under average conditions of environment, load and stress.
6. $n = 3$ to 4 should also be used with better known materials that are to be used in uncertain environments or subjected to uncertain stresses.
7. $n = 2$ for impact of very ductile materials where the small index of sensitivity results in low stress concentration factors and $n = 1.5$ for less ductile materials where a higher sensitivity will provide a larger factor of stress concentration.
8. $n = 1.5$ for design at higher temperatures based on the creep strength of the material that will result in a permissible plastic deformation over a preestablished life period.
9. Repeated loads—the factors of safety established in items 1 to 6 are acceptable but must be applied to the endurance limit rather than the yield strength of the material.
10. Castings, forgings, stampings and welded components— factors of safety here used do not usually vary appreciably from those presented above. Certainly the considerations involved are the same as those discussed at the beginning.
11. Special elements—factors of safety to be used with standard design elements, commercially available, should be those recommended for them by reliable manufacturers and/or by established codes for design of machines.
12. Where higher factors of safety might seem desirable a more thorough analysis should be undertaken before deciding upon their use.

The large number of uncertainties presented as well as the generalities that had to be used in discussing the information contained herein provide sufficient proof of the fact that basic knowledge is limited. Therefore the subject is of necessity very fluid. As discoveries and experiment supply more data and practice more experience concepts, theories and factors will change accordingly.

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Laboratory Instruction in an Engineering Curriculum*

By N. C. EBAUGH

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Importance of Laboratory Instruction

Those of us who have been privileged to attend the annual meetings and the special summer schools conducted by this society know that there is always great interest shown in discussions about laboratory instruction.

The importance which we attach to labortory instruction in the Mechanical Engineering Department of the University of Florida can be illustrated by the fact that every course offered, with the exception of the Senior Seminar, either has laboratory work required as an integral part of the course or laboratory work is required in a parallel course. Also, the present value of the equipment in the Mechanical Engineering laboratories is approximately $400,000. Surely, we wouldn't approve an expenditure of this amount for equipment and about an equal sum for housing this equipment unless we felt that proper laboratory facilities were really important. I am including design laboratories as well as those of an experimental nature in this discussion.

Objectives of Laboratory Training

If we omit the broad objectives of all higher education such as character building, citizenship training, a knowledge of human nature, and the development of intellectual curiosity and initiative, and concentrate on the objectives of the technical content of an engineering curriculum, then laboratory training becomes inseparable from classroom instruction.

The technical content of an engineering curriculum is designed to do two things for the student:

1. To impart basic scientific and technical principles and knowledge, and to show how such knowledge is extended with the aid of mathematical and experimental procedures.
2. To give practice in the development of skill in the use of the engineering method as it applies to problems of design, production and administration.

The second item distinguishes the engineering curiculum from the pure science curriculum. Obviously, technical laboratories are necessary if a student is to be given a wide range of practice while in school.

Another method which has been used with good success to further increase the student's opportunity for practice over that offered only in school is the usual Industrial Cooperative Plan where the student spends some

* Presented at the organization meeting of the University of Florida Branch, December 3, 1947.

time in industry, while he is working toward a degree.

I have contended in the foregoing that the laboratory and classroom work in a field of study should not be considered as separate and distinct from one another but rather as parts of the same subject. However, there are some objectives of an engineering training which can be accomplished better in the laboratory than in the classroom. These are:

1. To teach the use and limitations of instruments for measuring, pressure, temperature, time, speed, area, heat of combustion, humidity, current, voltage, watts, power factor, stress, strain, work, etc.
2. To widen the student's acquaintance with engineering equipment, such as: engines, turbines, boilers, pumps, air conditioners, compressors, fans, milling machines, shapers, routers, motors, generators, levels, transits, etc.
3. To acquaint the student with the various test codes used in professional practice which have been developed by our professional societies.
4. To teach the engineering method of selecting and using instruments, equipment, and men for accomplishing a specific task in the field of research, design, or testing.
5. To give training and practice in the preparation of engineering reports.

Types of Laboratories

There are two types of laboratories in use in the colleges. Prof. Neil P. Bailey [1] of Rensselaer Polytechnic Institute calls one of these "Subject Matter Laboratories" and I would call the other "Equipment Testing Laboratories."

The first type would employ equipment which is designed for instructing in the subject matter of heat transfer, fluid flow, evaporation, drying, distillation, vibration, etc. The laboratory work in these subjects would be of a type which would drive home basic concepts and principles in a given field of subject matter without regard to their many specific applications to machinery or industry. Vacuum tube characteristics, properties of soils, photo-elasticity, and similar subjects might also be considered as being in this category.

Chemical engineering departments have probably been the leaders in the development of subject matter laboratories. Certainly, the majority of mechanical engineering departments have only scratched the surface in this direction.

I do not feel that subject matter laboratories alone are sufficient and that we should give up altogether the testing of equipment. Certainly, the second objective of the technical content of an engineering curriculum as stated before can not be readily accomplished without a reasonable number of equipment performance tests. Also, the five objectives of laboratory work just stated could not be accomplished properly without equipment performance tests. However, I feel that our laboratories should include better facilities for subject matter experimentation and a reasonable selection of modern equipment for performance testing.

Our laboratories furnish the best opportunity for visual instruction since the student works with the real article. Also, the "learn by doing" principle of

[1] Neil P. Bailey and James D. Devine, "Functional Laboratory Courses," THE JOURNAL OF ENGINEERING EDUCATION, Vol. 38, Page 1414, Oct. 1947.

teaching can here be employed to maximum advantage. The employment of these two pedagogical aids to learning is most important when presenting technical subjects.

Instructors Most Important

We can have the finest of intentions and agree on a wonderful set of objectives, but we still will not graduate outstanding students unless we have an outstanding staff.

A good instructor can develop fine potential engineers with meager laboratory facilities (for the benefit of administrative officers—a good instructor can develop better potential engineers with better laboratory facilities), and a poor instructor will still present a poor course with the finest of laboratory aids.

Certainly if an instructor expects to instill enthusiasm for the subject, develop skill in techniques, and develop the desire for a thorough knowledge of the subject in the student, he must display these characteristics himself. These desirable qualities are contagious and we should take steps to spread the disease. It goes without saying that the pleasing manner which we associate with an attractive personality goes a long way in doing this or any other job.

Our general policy in the Mechanical Engineering Department has been for the instructors to teach the same students in the lecture and laboratory parts of a given subject. This eliminates problems of correlation found in many schools where laboratories are sometimes in a separate department. Furthermore, it has been my contention that the laboratory work is an integral part of the subject and nothing should be done to convince the student otherwise.

Occasionally an instructor feels that he should have lecture work and that the laboratory work should be delegated to the younger and less experienced men on the staff. I think this shows a lack of appreciation of the part that the laboratory plays in the objectives of a technical education. I would even go so far as to say that the laboratory part of our technical courses is the most important part because it affords the student actual personal experiences which he will remember long after much of his classroom work is forgotten.

Two other things are helpful. One is to permit instructors to choose their courses in so far as is practicable, in accordance with their past experience, interests, and abilities. The other is to allow proper credit and recognition for laboratory teaching time. I am pleased to report that I have been successful for many years in convincing our administrative officers that an instructor's teaching load for laboratory work should be calculated on the contact hour basis on a par with his classroom work. I have long contended that it takes a more competent man to properly handle laboratory work than it does to teach in the classroom.

Laboratory Procedure

The Mechanical Engineering Department has subject matter laboratories parallel to Thermodynamics, Metallography and Heat Treatment, and Manufacturing Operations, and a mixture of subject matter and equipment testing laboratories parallel to Power Engineering, Internal Combustion Engines, Refrigeration and Air Conditioning.

Our general plan with respect to reports is to require a complete report

as outlined in the inside of the Engineering College report cover. After the student has demonstrated his ability to turn in a report in good English and proper form, we permit him to abbreviate the report and include only the results, summary and conclusions in subsequent reports. We operate on the plan of a small number of good reports rather than a large number of half baked ones.

In the case of equipment testing experiments, it is necessary to have a laboratory data sheet made out prior to the beginning of the test. In senior equipment testing work, one man is appointed as leader of the squad and it is his duty to confer in advance with the instructor with regard to proper instrumentation, preparation of data sheets, and the assignment of work to the other members of the squad. The appointment of squad leaders is rotated among the squad during the semester.

Conclusions

The main points that I have tried to make in this brief discussion on laboratory instruction may be summarized as follows:

1. Laboratory instruction is vital to the presentation of the technical content of an engineering curriculum.
2. Laboratory instruction should be considered as an integral part of a course and not as a separate course.
3. The instructor is the most important factor in the successful presentation of laboratory work and he should receive suitable recognition.
4. The amount of laboratory report writing done by the student should be kept within reasonable limits and emphasis should be placed on quality rather than on quantity.

New Horizons in the Field of Graphics*

By A. S. LEVENS

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It is essential to a full realization of the usefulness of graphics in engineering design, development, and research that we become aware of and prepare for a broader program in the field of graphics.

In view of the technological progress that has been made during the war period and will continue to be made in the years to come, there is necessity for widening the scope of the work in graphics. New attitudes and clear thinking on the part of engineering educators should result in bringing about a high regard for this field and an improved, expanded program in its preparation.

Most engineering curricula provide for but one year of training in graphics. To accomplish the full utilization of the possibilities of graphical representation and to provide a background for research work, it is necessary to enlarge college offerings in this field.

It is a well-recognized fact that today engineers must have a good foundation in English, mathematics, physics, chemistry, and graphics.

Post-war revisions of engineering curricula reflect careful planning of programs which not only stress fundamentals, but also recognize the importance of training in the humanities.

The limited time allotted to engineering drawing and descriptive geometry creates problems for those who are charged with the responsibility of planning courses which will provide adequate training in one of the most important languages of the engineer.

Many instructors have benefited from war training experiences—both in the development of more effective teaching methods, and in the establishment of useful contacts with industry. As a consequence, several schools are doing a much better job in the field of graphics today, whereas others have failed to vitalize and modernize their courses. In a number of instances no use whatever is made of visual aids or of practical applications in the various fields of engineering.

Much can be done to improve the teaching of graphics, and to impress engineers and faculty members with the importance of this field of work. Only too frequently teachers of graphics are satisfield with their labors in the elementary courses. If advancement and recognition of achievement are to be obtained, it is most essential that a vigorous plan of action be put into operation to improve the present attitude toward graphics.

Specifically, what is being done to improve the teaching of drawing at the high school level? Surely collegiate training in graphics could be at a higher level if university instructors

* Paper presented at the S.P.E.E. meeting, June, 1946, Washington University, St. Louis, Missouri.

TABLE I

PROFESSIONAL AND VOCATIONAL EXPERIENCE OF INSTRUCTORS
Average Number of Years' Experience

Teacher Group	Total Teaching	Teaching Drawing	Teaching Shop	Working Draftsmen	Working Craftsmen
H.S. Drawing	17.4	13.6	5.4	2.0	3.9
H.S. Drawing-Shop	15.5	10.9	12.7	0.92	5.6
H.S. Shop	11.0	2.9	10.4	0.03	8.7

would take part in the training of high school drawing teachers.

Some effort has been made in this direction. Professor John T. Rule directed two summer school courses for high school teachers of mechanical drawing during the summers of 1939 and 1940. He found that the high school teachers' knowledge of descriptive geometry is very feeble. Some of the men who had been teaching the subject for years were delighted to discover such simple procedures as obtaining the edge and normal views of a plane. It was found extremely difficult to introduce any mathematical relationship. Professor Rule stated that "An algebraic equation generally caused a panic in the class." It is apparent that high school teachers of mechanical drawing are badly in need of fundamental training in descriptive geometry.

The work of Professor R. P. Hoelscher and his committee [1] was also a step in the right direction. They made excellent suggestions regarding content of beginning mechanical drawing courses in the high schools.

A survey conducted last year in the State of California revealed the urgent need for summer school programs to upgrade teachers of high school drawing, and such session was arranged for the summer of 1945. Due to lack of housing it was necessary to abandon the program. There was a good response to the questionnaire which was sent to teachers of drawing and shop. Forty-four of the 121 who replied indicated a desire to enroll. The professional and vocational experience attained by the drawing, drawing-shop and shop teachers groups is shown in the following Tables I and II.

A few general comments were:

"I have taught first year Mechanical Drawing and Woodshop but have had no instruction in either although I have minor in math. and science."

"The program should include shop or laboratory work to make a full program."

"Keep this course so simplified that a shop teacher can come back and use it from the vocational angle."

"I feel that a course of the 'graduate seminar' type would be best."

"There are too many teachers of drawing classes (general secondaries) who do not know the subject."

"Would like to suggest that uniform courses of study be planned, approved and adopted for use in all schools in this state and that informational and achievement tests be provided as a basis to accurately determine student achievement."

Another attempt will be made to offer a summer session program as

[1] "Syllabus of Mechanical Drawing Courses for Illinois High Schools," *Univ. of Ill. Bulletin*, Vol. XXXII, May 7, 1935, No. 36.

TABLE II

FORMAL ACADEMIC TRAINING

Teacher Group	Number Replies*	Number Degrees	A.B. B.S.	A.B., B.S. Engineering or Ind. Arts	M.A. M.S.	M.A., M.S. Engineering or Ind. Arts
H.S. Drawing	41	9	17	7	6	2
H.S. Drawing-Shop	25	4	7	9	3	2
H.S. Shop	34	13	12	7	2	0

* Junior college replies not included.

soon as conditions permit. It should be mentioned that credit courses have been approved for this purpose.

Later, it should be possible to offer advanced work in descriptive geometry, shop methods, and phases of graphical mathematics. These courses could be part of a program leading to a Master's degree in Industrial Arts or in Industrial Education.

Another area which should be developed is in the training of physicists and chemists to enable them to use the graphic language effectively. During the war period, engineering personnel who were charged with the responsibility of "getting the job done and making it work" were frequently handicapped by the physicists' and chemists' lack of ability to prepare understandable sketches from which it was necessary to make design and production drawings.

Physics and chemistry curricula should provide for courses in graphics which would stress freehand sketching and an understanding of the fundamentals of orthogonal projection. Research and development work of the physicist and chemist will be facilitated by such training.

For a more complete program, then, at the college level, training in the field of graphics might well include:

1. Advanced Descriptive Geometry —both graphic and algebraic.
2. Nomography.
3. Projective Geometry.
4. Curve Fitting.
5. Principles of Photogrammetry.
6. Vector Analysis.
7. Graphical and Mathematical Lofting.
8. Production Illustration.
9. Representation and Analysis of Experimental Data.
10. Graphical and Mechanical Computations.

A few engineering schools, properly staffed, should undertake the development of such a program which would greatly expand the view of the field.

The engineer who is active in design, development, or research should have a fuller appreciation of graphic methods. A working knowledge of nomography, to cite but one example, would enable the engineer to make more effective use of functional scales. It would also make possible the design of time-saving nomograms which are so advantageous to the designer. Engineers should be acquainted with the works of Lipka, O'Cagné, Allcock and Jones, and others in the field of nomography.

Again, an appreciation of graphical and mathematical lofting methods is

invaluable to the engineer concerned with streamline design. He should examine the works of Apalategui and Adams,[2] and that of Liming [3] who have presented the application of analytic geometry to lofting and tooling.

It is incumbent upon those engaged in engineering research, development and design to understand the graphic methods of integration and differentiation. Problems which involve velocity and acceleration determinations frequently are best solved by graphic calculus, although it is true that numerical and mechanical methods may be employed also.

The determination of shears, moments, slopes, and deflections of beams, subjected to various loadings, can be effected by graphic integration.[4] The center of gravity, moment of inertia, and surface area of the human body [5] are best found by the same method—graphic integration.

Differential equations may be solved graphically, and in a number of cases it is the simplest method to use. A very good example is presented in connection with a study of "The Behavior of a Hot-Wire Anemometer Subjected to a Periodic Velocity." [6]

The representation and analysis of experimental data is, indeed, most important in research work. Engineers should have an appreciation of graphic, numerical, and mechanical methods which are employed. At least, a "nodding" acquaintance with such writings as "Treatment of Experimental Data" by Worthing and Geffner; "Graphical and Mechanical Computation" by Lipka, especially Part II dealing with "Experimental Data"; "Numerical Mathematical Analysis" by Scarborough; and "Applied Mathematics in Chemical Engineering" by Sherwood and Reed, is certainly in order.

The engineer should be thoroughly trained in descriptive geometry which is basic to an understanding of the theory of projection and the application of fundamental principles to the solution of many space problems arising in the various branches of engineering.

Much has been said in the past about descriptive geometry. In many instances the antipathy shown toward this field is the result of a "stereotyped bias" which stems from sad experiences that faculty members may have had as students. Unfortunately, most of them have not kept abreast of the changes that have taken place in recent years.

The value and practical application of the principles of descriptive geometry in research are well illustrated by a project now in operation in the Department of Engineering at the University of California at Berkeley. The research is in the field of prosthetic devices—the improvement of the design of artificial legs. The program is being carried out under the auspices of the Committee on Prosthetic Devices of the National Research Council. The work is directed by Professor H. D. Eberhart of the Division of Civil Engineering, and associated with him are Dr. Verne T. Inman, Clinical Assistant Professor in Orthopedic Surgery, Dr. John B. Saunders, Pro-

[2] "Aircraft Analytic Geometry; Applied to Engineering Lofting and Tooling," McGraw-Hill, 1944.

[3] "Practical Analytic Geometry With Applications to Aircraft," Macmillan, 1944.

[4] "Fundamental Theories of Graphical Integration" by M. S. Douglas, *Civil Engineering*, August 1934.

[5] *Human Biology*, Vol. 10, No. 3, Sept. 1938, "Contour Maps, Center of Gravity, Moment of Inertia and Surface Area of the Human Body" by A. P. Weinbach.

[6] By Martinelli and Randall, *Transactions A.S.M.E.*, January 1946.

fessor of Anatomy, both from the University of California Medical School, Professor T. D. McCown of the Anthropology Department, the author, and others.

Initially, the program embraced the study of the mechanics of motion of the leg—involving measurements of the ranges of motion in space, including rotations, of the major elements of the legs during locomotion, and in particular, the study of the action, in the major joints of the lower extremity, *e.g.*, the hip, knee and ankle joints—and a study of the literature pertaining to locomotion, prostheses, and amputations.

Another aspect of the initial program included an analysis of the phasic action of muscles in the leg for both normal individuals and amputees by means of electromyography. Later the scope of the work was enlarged to include a statistical study of both arm and leg sizes, with the view of assembling information which might be used to establish three-dimensional standards, thereby making it possible to mass produce parts of the prostheses.

Since then, the work has been expanded further to include structural analysis, design, and accelerated testing of various types of prostheses. The purpose of this phase of the project is to bring all possible information to bear on the subject of choice of materials for adequate strength, minimum weight and proper weight distribution, type of design, maximum life, minimum cost and the development of methods for accelerated testing of parts, subassemblies, and complete limbs for the proper evaluation of performance. Upon the proper correlation and analyses of the study of locomotion, gait, muscle action and dynamic forces, depends the development of rational design in prosthetic mechanisms for the lower extremity.

Of special interest to persons engaged in the field of graphics, is the study of locomotion. The analysis of the behavior of the hip and knee joint during locomotion, and, in particular, the determination of the relative transverse rotation between the bones at each joint presents a difficult problem.

An effective technique has been developed to obtain necessary data. Under sterile precaution and local anesthesia, 2.5 mm. stainless steel pins are drilled firmly into the cortices of the various bony prominences adjacent to the hip and knee joints. Targets, consisting of a thin wooden cylinder and two attached spheres, are fastened to the pins. Pins 1, 2, and 3 are at the iliac crest of the pelvis, at the internal (medial) condyle of the femur, and at the upper portion of the tibia (tibial tubercle), respectively. Motion of the targets is recorded by three 35 mm. cameras operating at 48 frames per second, and positioned at right angles to three mutually perpendicular coordinate reference planes. The cameras operate simultaneously and in this manner, top, front and side views of the subject are obtained. A clock mechanism makes it possible to identify three related frames which are studied from enlarged images projected upon ground glass.

Since a coordinate reference system is employed, it is possible to establish the three coordinates of each target from which true angular values may be obtained.

Further studies have been made to show the rotation of each pin about a vertical axis, and also the rotation of one pin relative to the others. At the early stages of this phase of the research, methods had to be developed

for the reduction of the photographic data to true magnitudes. Essentially, this consisted of a relatively simple scheme of converting perspective coordinates of the targets to orthogonal coordinates.

Later, it was found that if the pins were placed as nearly parallel to the H-plane as possible, the apparent angle between the pins, as observed from a camera position above the subject, was sufficiently accurate to justify direct readings. Before adopting this method, it was necessary to prove, by descriptive geometry principles, that the pins could make an angle of about 10° with the H-plane and yet give angular values that were within the limits of the accuracy of measurement.

The fundamental problem in this study was that of finding the angle between two skew lines from related perspective projections, rather than from orthogonal projections. In addition, the analysis of the data afforded an excellent opportunity to use the powers of "visualization." Sometime in the future more details of this fascinating project may be disclosed.

In conclusion, the foregoing may be summarized in this manner. Teachers in the field of graphics must become aware of the importance of their work and the wide areas of application. They must not be satisfied to remain in an "academic rut." An aggressive program of activity must be undertaken. Faculty members who are not especially interested in graphics must be made conscious of its importance—at least to the extent of a sincere appreciation of its value in engineering.

It is of vital importance that every effort be made to:

1. Improve the effectiveness of high school teaching of drawing.
2. Revitalize and modernize present college level courses in graphics.
3. Work with colleagues in other technical fields, in order to impress them with the usefulness of graphic methods and applications.
4. Induce collegiate physics and chemistry departments to include graphics courses in their curricula.
5. Encourage teachers of graphics to participate in research work and to become actively interested in fields allied to graphics.

These efforts, if successfully performed, should give dignity to and respect for the work in graphics.

The Flow Chart for Student Records

By FREDERICK H. THOMAS

Professor and Head, Department of Industrial Engineering, University of Buffalo

The flow chart, in the keeping of student records, apparently does not have as wide usage as its advantages would indicate. A number of times, in the past years, the writer has come across students who, partially because of inadequate advisement and partially because of lack of proper checking by the student, have arrived at the first or even second semester senior stage lacking essential freshman or sophomore subjects. Of course the subjects were not requirements for later work, or the situation would not have occurred.

The problem of putting record data before both adviser and student in such a way as to preclude the possibility of such situations occurring led to the use of flow charts, examples of which are shown here.

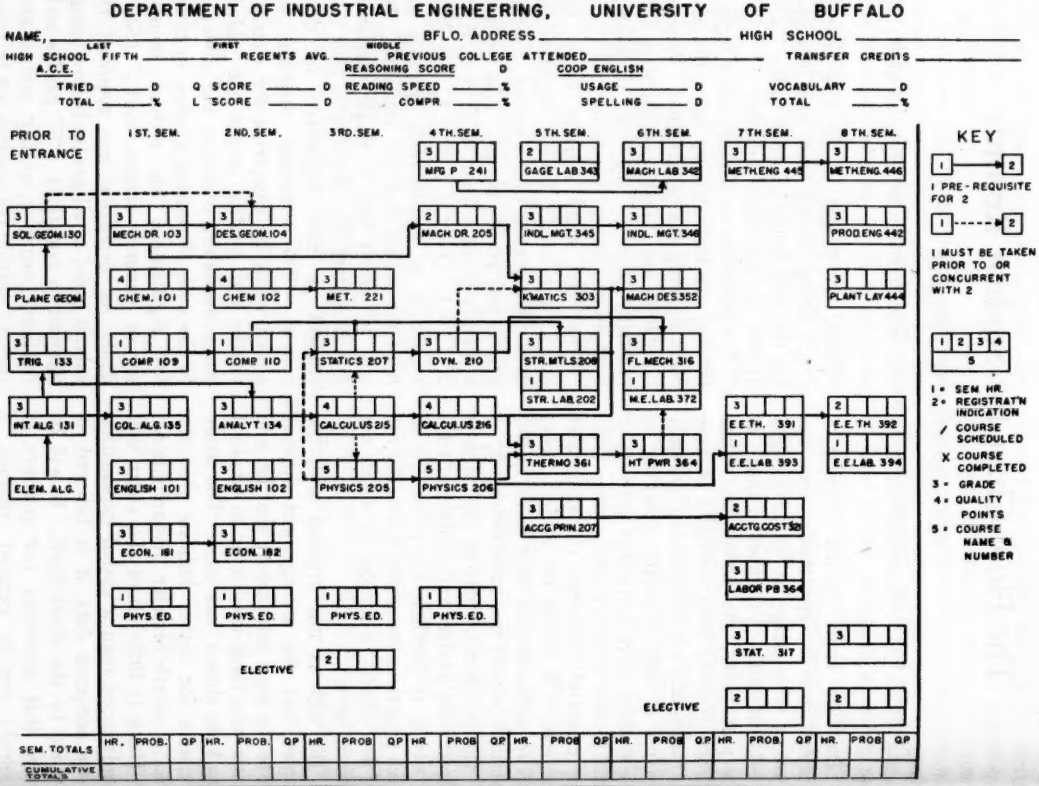
The idea is not original with the writer, but the arrangement appears to be the most satisfactory that he, and those who have used it or to whom it has been shown, has seen. The many requests for copies indicate that the idea is worth broader dissemination.

There is little about the chart that needs more than a casual explanation since adequate data, it is believed, is carried by the chart itself. It will be noted that semesters (or quarters, if desired) are in vertical columns, a column being included for entrance requirements. As we have many applicants deficient in mathematics, three courses, normally taught in the High School, are taught in the University, credit being turned back and increasing the total hours of work in the University an equivalent amount.

Prerequisites, or simultaneous registration, are indicated by lines, the arrows showing the progression. Where no arrows are shown, prerequisites are normally those of the year of work; sophomore, junior, or senior.

The four small squares carry, in order: the credit hours, registration in and completion of the course, course grade, and quality points. (As we use a quality point system of A = 3, B = 2, C = 1, D = 0, F = − 1, the last square is of considerable interest to both the school and the student). It will be noted that a single diagonal line in square No. 2 indicates that the student is now registered in this course. The crossing diagonal is added when he completes the course. Grade and quality points are added when available, which is not always, in the case of passing grades, in time for registration for second semester or summer sesson work. (Students on probation are required to submit proof of all grades before being allowed to register.) "F" grades and resultant negative quality points are entered outside the squares but in relative position.

Courses which must be taken together are contained in a combined block as shown in the last four semes-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PRIOR TO ENTRANCE
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3RD. SEM.
4TH. SEM.
5TH. SEM.
6TH. SEM.
7TH. SEM.
8TH. SEM.
SOL. GEOM. 130
PLANE GEOM.
TRIG. 133
INT. ALG. 131
ELEM. ALG.
MECH. DR. 103
DES. GEOM. 104
CHEM. 101
CHEM 102
MET. 221
COMP. 109
COMP. 110
STATICS 207
DYN. 210
COL. ALG. 135
ANALYT 134
CALCULUS 215
CALCULUS 216
ENGLISH 101
ENGLISH 102
PHYSICS 205
PHYSICS 206
ECON. 181
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PHYS. ED.
ELECTIVE
MFG P. 241
MACH. DR. 205
KINEMATICS 303
STR. MTLS. 208
STR. LAB. 202
THERMO 361
ACCG. PRIN. 207
GAGE LAB 343
MACH LAB 342
INDL. MGT. 345
INDL. MGT. 346
MACH DES. 352
FL. MECH 316
M.E. LAB. 372
HT PWR 364
METH. ENG. 445
E.E. TH. 391
E.E. LAB. 393
ACCTG. COST 321
LABOR PB 364
STAT. 317
ELECTIVE
METH. ENG. 446
PROD. ENG. 442
PLANT LAY 444
E.E. TH. 392
E.E. LAB. 394
KEY
1 PRE-REQUISITE FOR 2
1 MUST BE TAKEN PRIOR TO OR CONCURRENT WITH 2
1 SEM. HR.
2 REGISTRATN INDICATION
/ COURSE SCHEDULED
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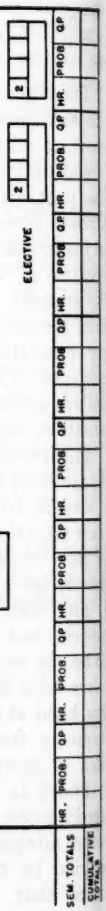
3 GRADE
4 QUALITY POINTS
5 COURSE NAME & NUMBER
SEM. TOTALS
CUMULATIVE TOTALS
HR. PROB. QP

ter columns. This avoids any chance of the student being registered in only one of the courses.

Totals, by semester, of credit hours and quality points are recorded at the bottom of each column, both as semester totals and cumulative totals. In this way, both adviser and student can tell at a glance the standing at any time, improvment or deterioration from semester to semester, and the minimum requirements to attain graduation status. Probationary status is also indicated here.

Additional data of any sort can be placed at the top of the sheet or on the back, whichever is more convenient. We use only the front of the sheet; the data shown includes results of Regents and aptitude tests.



Solutions of the Transformed Weber Equation as an Aid in Teaching Legendre Polynomials and Bessel Functions

By FRANK McL. MALLETT

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Introduction

This work had its beginning in a course in Mathematical Aeronautics given in 1947 by the Department of Aeronautical Engineering at the Ohio State University, in the teaching of which the author assisted. In looking through Ince's "Ordinary Differential Equations" (Reference 3) the idea suggested itself that the Weber Equation and the associated Transformed Weber Equation would make good material to introduce the study of solutions in infinite series of ordinary linear differential equations with variable coefficients. Upon working out some of the details connected with the solutions, which are not given, at least in the common literature on differential equations, it soon became evident that the Transformed Weber Equations and its solutions provided an even better example than had at first appeared, as will be explained below. When tried out in class, the work proved to be a successful introduction to Legendre Polynomials and Bessel Functions.

The mathematics is relatively simple. This work makes its claim to interest because of its value to a teacher who is presenting Legendre Polynomials and Bessel Functions to a class of engineering or other science students who, it will be admitted, often find it difficult to jump directly into these topics.

The Teaching Problem

The value of Legendre Polynomials and Bessel Functions to engineers and physicists is well known. References 2 and 5 give numerous applications. Therefore these topics are usually included in courses in mathematics designed for students of engineering or physics at the upperclass or graduate level. Without attempting an exposition even approaching that given in Reference 6, the instructor must usually include at least as much material as is given in References 1 or 4. (Indeed, these books may well be used as texts in engineering mathematics.) The professional mathematician may be too easily inclined to think that none of this work is difficult, and it is not, for a mathematics major. However, the engineering student does not have time to be a mathematics major, and when he meets some of these topics he often experiences no little difficulty. Thus it seems that if the instructor can in any way ease the suddenness with which

these topics are introduced it is worth while to do so.

In this particular case the situation will be something like this: The student will already have had some of the special cases of differential equations of low order and/or degree which can be integrated. He will have studied linear equations of higher order with constant coefficients. This of course, will cause little difficulty, and many problems of engineering and physics can be reduced to such equations by simplifying assumptions, and solutions found. All of this is fine. The student may also have been introduced to the general linear ordinary differential equation with variable coefficients with some general theorems about solutions and linear combinations of solutions. He will possibly be a bit hazy about some of this, and not sure that it is useful. It is doubtful if he knows what the Wronskian is, or why.

Now consider the problem facing the instructor at this point. The time has come to move on. He must explain to the class, possibly in the words of Professor Ince,* that "Apart from equations with constant coefficients, and such equations as can be derived therefrom by a change of the independent variable, there is no known type of linear equation of general order n which can be fully and explicitly integrated in terms of elementary functions. . . . Thus in a great majority of cases, equations which arise out of applied mathematics and which are not reducible to equations with constant coefficients, have as their solutions new transcendental functions." As we have already hinted, the Legendre Equation and the Bessel Equation are now knocking at the door; indeed, they are about to enter. At this time the Transformed Weber Equation may be useful. Its solutions, as will be seen below, have properties analogous to some of the properties of both the Legendre Polynomials and the Bessel Functions. Thus much of the strangeness that these "new transdendental functions" have for students will be removed by studying first these solutions of the Transformed Weber Equation. Furthermore, these solutions are easier to derive, from the standpoint of mathematical manipulation, than are the Legendre and Bessel Functions. For these reasons they make a good transition for the student into the study of the latter functions. The student is given an opportunity to grasp the point, that the solution, in the form of an infinite series, can be used to define a new function. Then when he studies the Bessel Equation, in particular, he will not be so apt to fail to understand this because of a welter of mathematical detail.

The Transformed Weber Equation and Solutions

The Weber Equation is†

$$Y''+(n+\tfrac{1}{2}-\tfrac{1}{4}x^2)\,Y=0, \qquad (1)$$

where, as usual, primes denote differentiation with respect to the independent variable x.

If the transformation

$$Y=e^{-\frac{1}{4}x^2}y \qquad (2)$$

is substituted into (1), the result is the Transformed Weber Equation

$$y''-xy'+ny=0. \qquad (3)$$

The method of solution of equation (3) is, of course, that of writing y, a

* See page 158 of Reference 3.

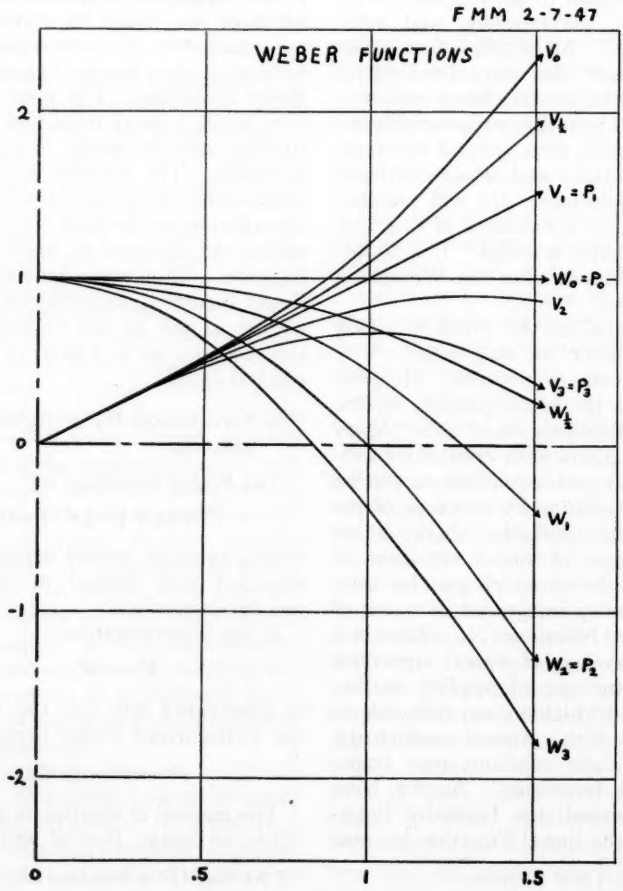
† See page 159 of Reference 3.

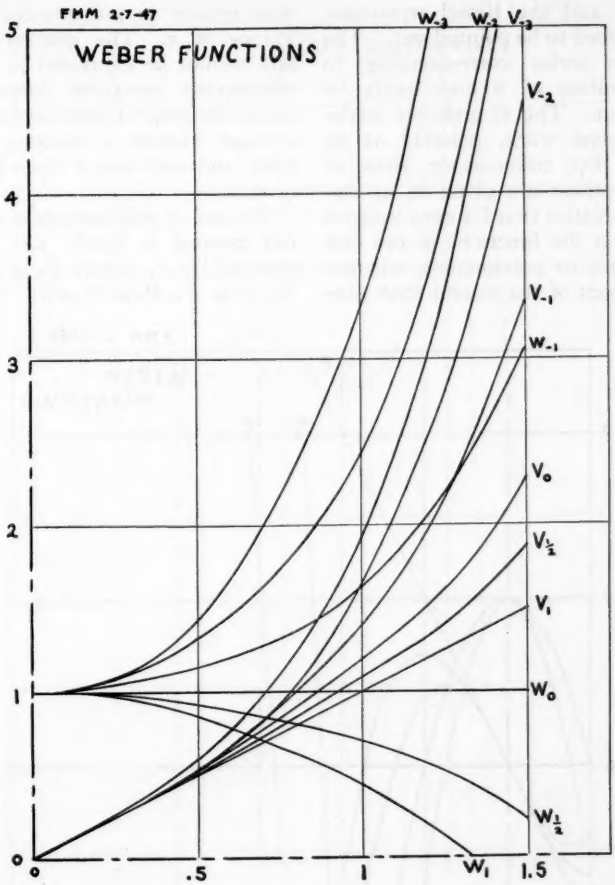
function of x, as a power series in x with undetermined coefficients a_r. Substituting this series and its first and second derivatives in the equation, and equating to zero the coefficients of the resulting series, there results what is called the "recurrence formula"

$$(r+2)(r+1)a_{r+2}=-(n-r)a_r, \quad (4)$$

which can be used to determine the coefficients of the original power series which is a solution to the equation. By the nature of the formula (4) we have free choice of the first two coefficients, a_0 and a_1. Choose first $a_0=1$, $a_1=0$. Then choose $a_0=0$, $a_1=1$. Two particular solutions are thus found:

$$y_1=1-\frac{n}{2!}x^2+\frac{n(n-2)}{4!}x^4 -\frac{n(n-2)(n-4)}{6!}x^6+\cdots, \quad (5)$$





$$y_2=x-\frac{n-1}{3!}x^3+\frac{(n-1)(n-3)}{5!}x^5 -\frac{(n-1)(n-3)(n-5)}{7!}x^7+\cdots. \quad (6)$$

It is not hard to show that each of these converges for all finite $|x|$.

If $a_0=c_1$ and $a_1=c_2$ are chosen, the result is

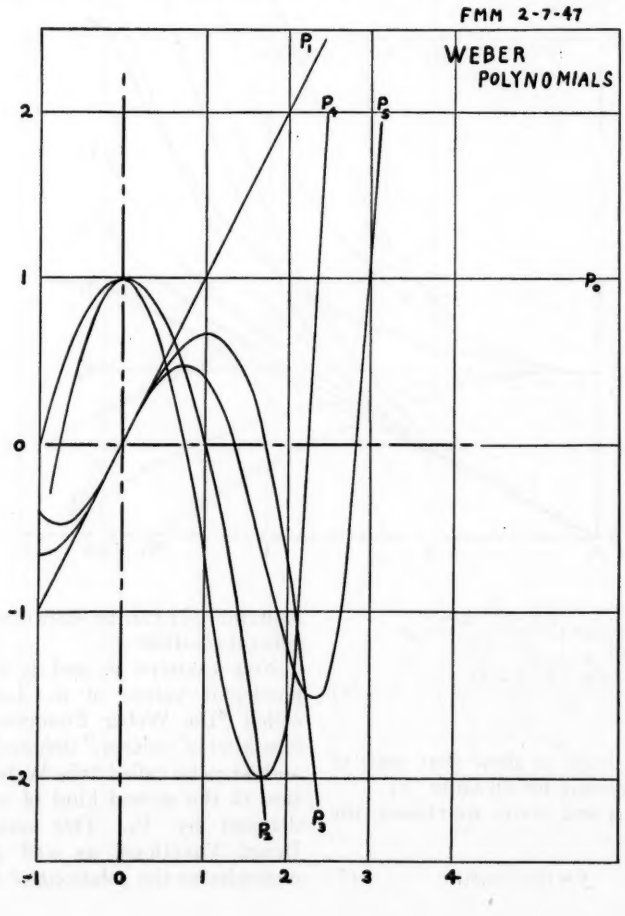
$$y=c_1y_1+c_2y_2. \quad (7)$$

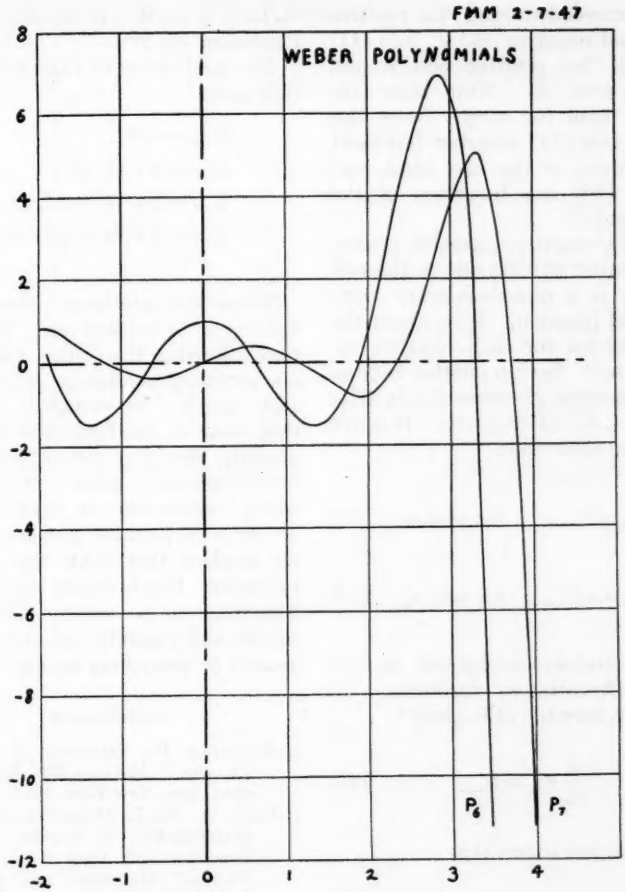
Equation (7) can be shown to be the general solution.

Now examine y_1 and y_2 for some particular values of n. Let y_1 be called "the Weber Function of the first kind of order n," denoted by W_n, and let y_2 be called "the Weber Function of the second kind of order n," denoted by V_n. This analogy to Bessel Functions, as well as other analogies to the solutions of both the

Legendre and the Bessel equations, does not need to be pointed out. The particular series corresponding to various values of n may easily be written out. This is probably advisable in class work, possibly as an exercise. For convenience, some of these functions are given in an appendix. Notice that for even integral values of n the functions of the first kind reduce to polynomials, whereas the functions of the second kind likewise reduce to polynomials for odd values of n. The general solution still cannot be expressed in terms of elementary functions, however, because the general solution for a given n must include a function of each kind, and only one of them is a polynomial.

The set of polynomials is not without interest in itself. Let them be denoted by P_n, where P_0 is W_0, P_1 is V_1, P_2 is W_2, P_3 is V_3, etc. Then it is





easy to show that

$$\frac{d}{dx}P_n = P_{n-1} \qquad \text{for odd } n, \quad (8)$$

$$\frac{d}{dx}P_n = -nP_{n-1} \qquad \text{for even } n. \quad (9)$$

Note also that the set of transcendental functions T_n where T_0 is V_0, T_1 is W_1, T_2 is V_2, etc., has the following differentiation formulas:

$$\frac{d}{dx}T_n = T_{n-1} \qquad \text{for even } n, \quad (10)$$

$$\frac{d}{dx}T_n = -nT_{n-1} \qquad \text{for odd } n. \quad (11)$$

Inspection of the series for negative integral orders shows that if we extend our set of transcendental functions T to negative integers in such a way that T_{-1} is V_{-1}, T_{-2} is W_{-2}, T_{-3} is V_{-3}, etc., then the differentiation formula (10)

can be extended to read "for positive even n and negative odd n" and (11) will read "for positive odd n and negative even n." Note that (10) does not hold for $n=0$. Note also that (9) and (11) together represent the functions of the first kind, and (8) and (10) the functions of the second kind.

Thus for negative integral orders, for each order at least one of the two functions is a non-elementary transcendental function. How about the other function for each negative integral order? Set up another infinite set of functions E where E_{-1} is W_{-1}, E_{-2} is V_{-2}, E_{-3} is W_{-3}, etc. It is not difficult to show that

$$\frac{d}{dx}E_{-n}=E_{-n-1} \quad \text{for even } n, \tag{12}$$

$$\frac{d}{dx}E_{-n}=nE_{-n-1} \quad \text{for odd } n, \tag{13}$$

bearing obvious similarities to the other differentiation formulas. In particular, formula (13) gives

$$\frac{d}{dx}E_{-1}=E_{-2}. \tag{14}$$

But inspection shows that

$$E_{-2}=x\cdot E_{-1} \tag{15}$$

and (14) and (15) together give the equation

$$\frac{d}{dx}E_{-1}=x\cdot E_{-1}. \tag{16}$$

The differential equation (16) is easily solved (variables separable) to give

$$E_{-1}=e^{\frac{1}{2}x^2}. \tag{17}$$

In fact, $E_{-1}=W_{-1}$ is the MacLaurin's Expansion for $e^{\frac{1}{2}x^2}$.

The application of (12) and (13) to (17) gives

$$E_{-2}=x\cdot e^{\frac{1}{2}x^2},$$
$$E_{-3}=(1+x^2)\cdot e^{\frac{1}{2}x^2},$$
$$E_{-4}=(x+\tfrac{1}{3}x^3)\cdot e^{\frac{1}{2}x^2},$$
$$E_{-5}=(1+2x^2+\tfrac{1}{3}x^4)\cdot e^{\frac{1}{2}x^2},$$
etc.

There are doubtless other details waiting to be worked out. However, time alloted in the course will usually not permit presentation of too many such items. Nevertheless, showing that some of the functions are polynomials, deriving the differentiation formulas, and other such details which foreshadow the work to come all serve a valuable purpose in that the student then finds the work on Legendre Polynomials and Bessel Functions to be merely different in details and possibly one step harder, instead of something entirely new.

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Appendix

$$W_0 = P_0 = 1$$

$$V_0 = T_0 = x + \frac{1}{6}x^3 + \frac{1}{40}x^5 + \frac{1}{336}x^7 + \cdots$$

$$W_1 = T_1 = 1 - \frac{1}{2}x^2 - \frac{1}{24}x^4 - \frac{1}{240}x^6 - \cdots$$

$$V_1 = P_1 = x$$

$$W_2 = P_2 = 1 - x^2$$

$$V_2 = T_2 = x - \frac{1}{6}x^3 - \frac{1}{120}x^5 - \frac{1}{1680}x^7 - \cdots$$

$$W_3 = T_3 = 1 - \frac{3}{2}x^2 + \frac{1}{8}x^4 + \frac{1}{240}x^6 + \cdots$$

$$V_3 = P_3 = x - \tfrac{1}{3}x^3$$

$$W_4 = P_4 = 1 - 2x^2 + \tfrac{1}{3}x^4$$

$$V_4 = T_4 = x - \frac{1}{2}x^3 + \frac{1}{40}x^5 + \frac{1}{1680}x^7 + \cdots$$

$$V_5 = P_5 = x - \frac{2}{3}x^3 + \frac{1}{15}x^5$$

$$W_6 = P_6 = 1 - 3x^2 + x^4 - \frac{1}{15}x^6$$

$$V_7 = P_7 = x - x^3 + \frac{1}{5}x^5 - \frac{1}{105}x^7$$

$$W_{-1} = E_{-1} = 1 + \frac{1}{2}x^2 + \frac{1}{8}x^4 + \frac{1}{48}x^6 + \cdots$$

$$V_{-1} = T_{-1} = x + \frac{1}{3}x^3 + \frac{1}{15}x^5 + \frac{1}{105}x^7 + \cdots$$

$$W_{\frac{1}{2}} = 1 - \frac{1}{4}x^2 - \frac{1}{32}x^4 - \frac{7}{1926}x^6 - \cdots$$

$$V_{\frac{1}{2}} = x + \frac{1}{12}x^3 + \frac{1}{96}x^5 + \frac{1}{896}x^7 + \cdots$$

The Mechanics of Aristotle and Archimedes*

By HARVEY F. GIRVIN

Professor of Engineering Mechanics, Purdue University

It is gratifying to observe the increasing interest which is being shown in the historical background of our basic sciences. At Purdue largely due to the influence and efforts of Dean Potter and a trust fund provided by Mrs. Edna G. Goss in memory of her husband, a former dean of engineering, the William Freeman Goss Library of the History of Engineering is gradually growing into a valuable collection of historical material. At the present time there are something over 3500 titles in general science and the various fields of engineering on its shelves.

Someone has said: "No man is civilized or mentally adult until he realizes that the past, the present, and the future are indivisible." It has also been said that history is the plaything of old men and that young men have too much to do to become well informed on the accomplishments of the past. This is, no doubt, at least partially true, but I believe the remedy is simple and easily attainable in the basic physical sciences. In the broader and less tangible fields of the social sciences and government the task would be more complex but could be accomplished.

I think the essential information needed to make history of science a workable tool for practical use could be reduced to a rather small volume of attractively stated and easily absorbed material. It is possible that such historical material should be written by economically minded engineers rather than by our more eloquent and verbose friends, the professional historians. Then if by becoming acquainted with this not too taxing body of historical material the younger generations of the world could be induced to become historically wise, we might have at least a partial solution of our present world problems.

During the period 600 to 500 B.C. some of the Greek thinkers traveled in Egypt and the East, where they borrowed the elements of their astronomical and mathematical learning. This probably furnished the mental stimulus which started the Greek School of Philosophy led first by Thales and later during the third and fourth centuries B.C. by Hippocrates, Aristotle and Euclid.

The Greeks made the first attempt to collect and organize universal knowledge that the world had known. They were enthusiastic workers who were exceedingly anxious to explain everything and also apparently had unlimited confidence in their ability to do so, probably because they were the world's pioneer research workers and had not experienced the disconcerting influence of the cruel cold light of experimentally determined facts.

There were two general methods of attack available to the Greeks. The first was to observe and examine avail-

* Presented at the Illinois-Indiana Section Meeting of the A.S.E.E., Terre Haute, May 10, 1947.

able facts and formulate their conclusions on the basis of this evidence. The other was to start from some assumption and by process of speculation develop a theory or principle. They chose the latter method, probably because of their dislike for physical labor, which they thought degrading and suitable only for slaves.

Almost 2,000 years after the establishment of the Greek School of Philosophy the teachings of Aristotle were still the accepted code of the civilized world. This is indisputable evidence of the authority and prestige which Greek Philosophy had attained. This was not the result of its own efforts nor due to the weight of its wisdom. It was because of its adoption by the Church as its accepted scientific code. For a considerable period of time the Greek Philosophy was able to supply usable answers to many of the problems with which the Christian church had to cope.

Aristotle who lived from 384 to 322 B.C. and Archimedes from 287 to 212 B.C. along with their associates and pupils were responsible for the pioneer thinking in the field of mechanics. The whole first fifty years of Aristotle's life were devoted to the extended education necessary to prepare him for his career as a philosopher, a title first assumed by the author of the Pythagorean Theorem.

From his 18th to the 38th year Aristotle was a pupil of Plato and then devoted the next twelve years to travel in the Greek world. At 50 he started his philosophical teaching which continued until his death at 63.

Plato thought Aristotle an exceptionally able, appreciative, industrious, but independent student who did not hesitate to criticize his teacher but who was always respectful.

Like many great thinkers during the period when education was a privilege attained by few and research was not supported by endowments or salaries paid directly by business, Aristotle had the advantages of financial security and position. Such an endowment seems to have been a necessary part of the equipment of most of the world's great thinkers. Few of our basic fundamental principles came out of garrets. Education and accomplishment in basic science required the leisure and security enjoyed only by the aristocrat.

Many Aristotelian fragmenta, some genuine, others not, covering a wide range of subject matter, over 40 titles, have been collected and published in different editions of his works. The variety of subject matter and changes in style of the writing have thrown considerable doubt on the authorship of some of the work. It may be that Aristotle, generally credited with being the greatest systemizer of knowledge in the Greek world, was also the inventor of the graduate thesis racket so profitably employed by some present day educators. R. Shute in his *History of the Aristotelian Writings* contends that there is no certainty that we have any treatise in the exact words of Aristotle. This statement has been disputed by others, but it seems it could be entirely possible if due only to the editorial work required during the passage of the years. It is, however, further justified by Aristotle's reply to a student who objected to Aristotle putting his lectures into writing. He said: "My lectures are published and not published, they will be intelligible to those who heard them and none besides." Apparently the Greeks believed that the sanctity of the pupil-teacher relationship should not be cheapened by making knowledge

available to those who did not seek to obtain it through the established channels.

Mechanics was not a major interest of Aristotle. Natural history, biology, psychology, logic, ethics, politics, rhetoric, and poetry were more to his liking. His work on mechanics appears under the title of Mechanical Problems and is now one of the titles whose authenticity is sometimes questioned. He recognized the horizontal lever acted upon by vertical forces as a physical phenomenon which was worthy of study. He apparently had some comprehension of the problem, but his attempts to explain the action of the lever are rather amusing. He says, "Why do small forces move greater weight by means of a lever when they have to move the lever added to the weight?" He answers, "Because a greater radius moves faster." Also, "Why does a small wedge split great weights? Is it because the wedge is composed of two opposite levers?"

Aristotle was more interested in moving objects than those at rest, which was a human reaction since moving objects offered a challenge to his naturally inquisitive mind, which static objects did not. To attempt to explain the motion of objects without first having established the basic concepts of force and mass could only lead to a descriptive rather than a factual and specific explanation. Such terms as "violent," "passive," and "natural," frequently appear in Aristotle's discussions of moving objects.

In attempting to explain why a stone thrown by the hand finally comes to rest he says, "There is motion communicated to the air, the successive parts of which urge the stone forward and that each part of this medium continues to act for some while after it has been acted on and the motion ceases when it comes to a particle which cannot act after it has ceased to be acted upon." This is somewhat like saying that the stone stops itself rather than that it is stopped by the resistance of the air; another quotation of similar character, "Why can a man throw a stone farther with a sling than with his hand? Is it that when he throws it with his hand, he moves it from rest, but when he uses the sling he throws it already in motion?" Aristotle also thought that a continually acting cause was needed to maintain motion. He did not know that force was needed only to change motion. Furthermore, he had no clear conception of density or specific gravity which probably was somewhat responsible for his theory that the velocities of falling bodies were directly proportional to their weight. This he states in the following manner. "The body is heavier than another which in equal bulk moves downward quicker." He also thought that objects floated because of their shape and that the essence of matter was to be found in such qualities as "hotness," "coldness," "wetness," and "dryness" even though he had access to the atomic theory and had rejected it.

His lack of understanding of the concept mass brought forth the following statement. "Why is it that neither very small nor very large bodies go far when we throw them? Is it that what is thrown or pushed must react against that which pushes it, and that a body so large as not to yield at all, or so small as to yield entirely and not react produces no push." There seems to be some recognition here of Newton's action and reaction.

Archimedes who began his work

about fifty years after Aristotle's death also was born on the right side of the tracks. His father was an astronomer and he was either a relative or a close friend of King Hiero of Syracuse. He is believed by many to have been the foremost mathematical genius the world has so far produced. Historians also disagree on the authenticity of the Archimedian records which now exist. So well informed an authority as T. L. Heath says, "There now exists no original Archimedean manuscript." He states that the information now available all came from a manuscript written in the 9th or 10th century and which has since disappeared.

Archimedes is believed to have obtained his early mathematical training in Alexandria from followers of Euclid. His geometrical solutions of curved surfaces were practically geometric integrations and could well have furnished Newton and Leibniz with the ideas which brought about the discovery of the calculus.

Archimedes, like many other geniuses, had great physical energy as well as great mental power. This is demonstrated by the large volume of original mathematical work of which he is supposed to be the author. There is work now in existence under nine titles and evidence that six additional volumes were written by him. His work on mechanics appears in two volumes called *Equiponderants* and *Centers of Gravity*. There is also evidence that some of the lost volumes contained material on center of gravity, balances, and levers.

Archimedes is credited with producing the first logical statement of the principle of the lever, but unfortunately, he like Aristotle worked only with the horizontal lever and vertical loads and therefore cannot be considered the author of the general principle of the lever. He did, however, have a more logical understanding of how it operated. He says: "Weights which balance at equal distances are equal. For if they are unequal take away from the greater the difference between the two, the remainders will then balance, which is absurd. Therefore the weights cannot be unequal. Unequal weights at equal distances will not balance, but incline toward the greater weight. For take away from the greater the difference between the two, the equal remainders will therefore balance and if we add the difference again they will not balance but incline toward the greater." He demonstrates by similar logic that unequal weights will balance at unequal distances, the greater weight being at the lesser distance; from which he concludes that bodies attached to a lever are in equilibrium when the distances from the point of support of the lever are inversely proportional to the weights. It appears that Archimedes thought of the weights as balancing each other and that he had no understanding of the modern concept of moment of a force, which Leonardo da Vinci discovered in 1499. Neither did Archimedes know anything about the principle of work.

Using a straight lever and two equal sized balls and later three equal sized balls with equal spaces between them, he demonstrated that there is a point at which the weight of the balls could be concentrated without changing the position of the lever or the center of gravity of each system. This he defines in the following manner. "In every heavy body there is a definite point called the center of gravity at which point we may suppose the weight of the body collected." From

these demonstrations we suppose Archimedes learned that force, pressure, or weight is essential to the study of material objects.

Most everyone is familiar with the famous Archimedean bath tub story. If not he can turn to the April 21, 1947, issue of *Time* and see Archimedes in the nude, as visualized by the Goodyear Rubber Company. While soaking in his tub Archimedes is supposed to have arrived at the principle of buoyancy, which he states in the following manner. "When a heavy body is entirely surrounded by liquid it is buoyed up or balanced in part by a force equal to the weight of the liquid it displaces." To Archimedes buoyancy was also a balance of weights or equilibrium, which is the manner in which he discusses the subject in his book, *Floating Bodies*.

It is now recognized that Archimedes was the first to have even a partially correct understanding of such basic fundamentals of mechanics as the lever, center of gravity, and buoyancy. It is for this reason that he, and not Aristotle is sometimes spoken of as the founder of mechanics. Dr. Karl T. Compton in adressing the 5th International Congress of Applied Mechanics at Cambridge, Massachusetts, 1938, credited Archimedes with the discovery of the principles of statics and hydrostatics. This, I would say, was a rather liberal statement in view of the work which had to be done almost 2,000 years later.

What then was the net value of the Greek contributions to the advancement of the science of mechanics. I believe that it was briefly that they gave the "ball its first push forward." They realized that there were problems to be solved and attempted to solve them by the only method they knew, their speculative method. Indirectly their effort were responsible for a backward pus which was almost equally strong.

The Aristotelian philosophy becam so built into the theological doctrine o the dark ages that the hierarchy of th Church feared that to cast out Aristotl would endanger the entire structure o Christianity.

About 1126 the Arab commentato Averroe spoke as follows. "No one i 1,500 years has been able to add an thing to his writings or to find in them error of any moment. He should b called divine rather than human." However the Natural Philosophy o Aristotle and his commentators wa soon to lose much of its prestige. I 1209 it was condemned by the Counc of Paris and this action was confirme by Pope Gregory IX in 1231, but b the middle of the century Albert Magnus and Thomas Aquinas had s rearranged and explained Aristotle writings that they were again the ac cepted authority of the Church i things scientific. It was at this tim that Roger Bacon (1214–1294) of Ox ford, one of the world's greatest visio aries, began to function as a prophe of the future scientific developme based on the experimental method. H began to create doubt in the minds o thinking men by such statements as "Without experiment nothing can b adequately known. The strongest ar guments prove nothing, so long as th conclusions are not verified by experi ence. Experimental science is th queen of sciences and the goal of al speculation." This was the beginnin of the effiective revolt against the con trol of things scientific by the Church It continued on through the Renais sance (1400–1600).

There appears to have been no fur ther work on the theory of mechani

until Leonardo da Vinci (1452–1519), Copernicus (1473–1543), Stevinus (1548–1620), and Galileo (1564–1642) could restrain their natural curiosity no longer. They started checking the teachings of the Greeks experimentally, and soon discovered discrepancies in their speculatively developed theories.

It is doubtful if the speculatively arrived at relationships and axioms of the Greeks would have lasted long if they had not been protected by the dogmatic authority of the Church's hierarchy.

Professor Whewell, the eminant English authority on the history of the physical sciences, says in his *History of the Inductive Sciences,* "There is no fundamental truth in the knowledge of science today which can be credited to Aristotle and his followers. Also there seems to be no physical doctrine today of which anticipation can be credited to Aristotle." Yet Aristotle is still considered by many to have been not only the world's first but its greatest collector and systemizer of knowledge.

Dr. Andrew D. White, former president of Cornell University, in his *Welfare of Science and Theology,* says Christianity retarded the development of the physical sciences at least 1,500 years by enforcing an acceptance of Aristotle's fallacious theories upon the Western world long after they had ceased to serve any useful or stimulating purpose.

At a recent press conference on his new book *On Understanding Science* Dr. James Bryant Conant, President of Harvard, said: "Science is on the offensive and extending into new fields. From all sides we feel a demand for more understanding of science and of what it can do for humanity." He also stated that nearly all scientific progress thus far was in the natural sciences. The social sciences, according to Dr. Conant, "have not given man much help in keeping up with the flood of revolutionary knowledge and techniques developed by the natural sciences."

Dr. Conant thinks that it is "because we have failed to assimilate science into our Western culture that so many feel spiritually lost in the modern world." To correct this condition and further a widespread understanding of science he suggests courses in the strategy and tactics of science using the historical approach and showing the arduous, eratic, and very human steps which man took in arriving at the basic concepts of science.

If we agree with Dr. Conant and I believe most of us do, then we should be doing some serious thinking on how to make the race between these two branches of science a real contest. Few champions break records without keen competition. We have plenty of evidence all around us of the evils caused by a concentration of economic and military power.

If advances in the physical sciences are going to continue to outrun those made in the social sciences, we can well expect only a bigger and better edition of the dark ages which will have to be followed by some sort of a Renaissance. We have two choices just as the Greeks had. We can slow down the advance of physical science or speed up the development of the social sciences. If we choose the latter method, one way to help will be for everyone to realize that the past, the present and the future are indivisible, and for those of us associated with the physical sciences to feel a responsibility to examine the social implications of our work.

Advancement of the Engineer Depends Upon the Individual, the School, and the Employer*

By E. I. FIESENHEISER
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The education of the engineer has recently received a great deal of attention. An article entitled "Some Thoughts on Engineering Education" by Donald M. Baker appeared in the A.S.C.E. *Proceedings* of April, 1946. Since then sixteen separate discussions of this article have been published, seven by educators, nine by practicing engineers. I have read these and have also noticed several other articles and committee reports on the subject of engineering education. Many constructive criticisms were offered. They did not, however, get beyond the stage of generalities. What I mean is that we were not told exactly how our curricula should be revised. I quote some of the criticisms from Mr. Baker's article:

"Engineering education should emphasize fundamental principles in subjects throughout the broad field of engineering. Specialization and study of advanced theories should be left for post-college study. The engineer graduate is primarily a trained, not an educated person. There is a strong tendency to build curricula around the particular qualifications of the individual faculty members. Engineers lack a 'dollar' sense, seldom appreciate the relation between cost, value, or profit. The attitude of the profession toward engineering registration was one of antagonism at first, but later developed into indifference or mild interest. Many men leave the practice of engineering for other fields. Rate of advancement to positions of responsibility is slow."

I am willing to accept some of these criticisms as valid. Primarily we as teachers are interested in the success and advancement of our graduates since they are the product of our schools and their success reflects upon our ability as teachers and largely determines the reputation of our schools. However, I am not willing to accept the entire responsibility as belonging to the school. I maintain that rate of advancement of the engineer graduate depends also upon the individual, the school, and the employer. I should like to discuss the thesis that the individual, the school, and the employer are the essential factors in the engineer's advancement. It seems to me that of these three factors the individual is the most important. That men have made a success as engineers without college training indicates that college training is not absolutely necessary, although we know it is a great help. The one who succeeds without it will be one who spends years in private study learning the hard way.

The person who will advance in engi-

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neering will be one who has personality and the ability to get along with others. He will have a natural liking for figures and computation. He will be an intelligent person, able to use what he knows and apply it to particular problems. He will have the capacity for hard work, not always pleasant work and sometimes tedious. The habit of study must be acquired and study must be continued for many years after graduation. The individual, at the time of graduation, must be willing to accept a position of small responsibility in order to learn a particular job and in order to give his employer a chance to find out just where he will fit into the organization and what responsibility he can carry. Patience and willingness to give a job a fair trial are desirable qualities.

Of course, the above qualities are needed for success in practically any field but they are so important for engineers that I believe it is useless for us to try to make engineers out of those who do not have them. Those who are not intelligent, who do not like computation, and who do not have the capacity for hard work should not be taken into our engineering schools. If they do get in they will drop out automatically if our standards are high enough.

The selection of an employer and especially the first one, is quite important and largely determines a man's future. Unfortunately this is often a matter of chance. A man takes a plunge into a particular job. There may not be much choice at the particular time of graduation. Some years there are few job opportunities. That was true when I graduated in 1930. This year there are many jobs available and a man has some choice. Starting salaries are about 100 per cent higher this year than in 1930. Our men are having a hard time deciding which job to take.

The attitude of the employer toward the young graduate is most important. There must be an opportunity for the young man to advance or he cannot advance. Many times there is little opportunity. The morale of the young men and their interest in their work must be kept high. This is largely a problem of management. I have become acquainted with practices in some prominent engineering offices where management seems to be at fault.

In one office a young graduate was assigned a rather difficult design job for which he lacked the proper experience. He was left entirely alone to do this work and was given no supervision. He kept at it for weeks in an attempt to perform without help. When finally he reported, his work could not be used and his efforts were wasted. In disgust, his superior refused to give him any more work, whereas a little supervision would have made this young man useful.

In another design office the manager discovered that a young graduate was a very good draftsman and could make a nice looking drawing. He kept the young man at this type of work constantly. This gave him no chance to do any actual design work or computation. After months of this the young graduate found employment in another office.

Last summer my work took me to an office near Boston. Here a young graduate engineer had been engaged to do drafting work and was doing quite well. There was a small job to be done involving some computing which I knew this young man could handle since it only involved figuring dimensions. I suggested to the man in charge that the young man be allowed to do this figur-

ing. His reply was that "this fellow will have to be a draftsman first before he becomes an engineer." He refused to turn over the work even though he did not have time to do it himself.

With such policies as these in effect in design offices it is no wonder that young engineers have low morale and do not advance. They are not allowed to demonstrate what they can do.

The function of the *school* in preparing the engineer for his work is the problem we are here to consider today. We do not accept all the responsibility for the engineer's success but only our share. Given good material to begin with and assuming that the student upon graduation will be able to find an employer with whom he can advance, the remaining responsibility is certainly ours.

Many students are applying for an engineering education these days, in fact, more than the facilities of most schools are able to take care of. This is true at Illinois Institute of Technology. As long as this situation exists the school can carefully select those who have the best chance for success. Applicants are given tests and the results of the tests together with the students high school records are considered by our director of admissions. The tests are psychological, reading, Form Board, Mathematics aptitude, mathematics preparation, and Chemistry aptitude. In addition the applicant is given the Kuder Preference Test to help determine what kind of work he will like and enjoy.' Many times this preference test reveals the fact that the applicant would not enjoy engineering work.

After the students have been selected and started on their studies each one is assigned to a particular faculty member for counseling. Counseling appointments are made by the Dean of Students. The faculty counselor is given the record of the entrance tests for the students he has to counsel. At the interview the personal problems and progress of the student are discussed. An attempt is made to analyze his problems and to help the student along. It is the duty of the faculty counselor to encourage the student to come in for conference whenever he feels help or advice are needed. The success of the counseling system, of course, depends upon the personalities of the faculty counselors.

At Illinois Institute of Technology the curriculum now requires twenty-four hours of credit in humanities or liberal studies. These studies consist of three English courses and two in Economics, a total of fifteen hours. For the remaining nine hours the student may elect to study either Government, History, or Sociology, preferably continuous study in one of these three fields. These twenty-four hours of liberal studies should broaden the individual or at least, we hope, provide an incentive to further reading and study in the liberal arts field.

If the remainder of our curriculum consisting of scientific and technical subjects is to be revised, frankly I do not know how it should be done. We teach the usual courses in Mathematics, Mechanics, Surveying, Structures, Sanitary Engineering, Fluid Mechanics, Testing Lab., Thermodynamics, Electricity, Geology, and Contracts and Specifications. I shall be glad to carry back to my Department Head any suggestions as to how the curriculum can be changed to the advantage of the Civil Engineer.

Perhaps it is the way in which the subjects are taught which ought to be improved Of all subjects Mathemati

seems to the most important as a foundation for other engineering studies. A few years after graduation most engineers forget the Calculus they learned and so lose the use of a very essential tool. I wonder if this is not due to hurrying through this subject. If more than a year's time is needed to teach Calculus thoroughly, then more time should be devoted to it. Perhaps an additional semester with more applications to engineering problems would correct this situation.

In teaching technical subjects the instructor can always start with fundamentals, and *should* do so. The application of fundamental principles to the particular problem should then follow. To be a good teacher the instructor must be able to explain "why" as well as "how." I believe that many criticisms now being leveled at engineering school curricula will be answered if the teaching of our present courses can be improved. What is taught is not as important as how it is taught.

A worthwhile project for a school to undertake is to sponsor an active student branch of the A.S.C.E. This will help the student become acquainted with practical problems outside of school, will help him to meet some practicing engineers, and help him to find his place "in the scheme of things."

Finally the student should be told that engineering is not easy, that it usually involves a great deal of work, that there is very little glamour to it. Then when he leaves school he will find the situation somewhat as expected.

United Nations Research Laboratories

In September 1946 the Economic and Social Council of the United Nations voted to adopt the following resolutions, submitted to it by the French delegation:

"The Economic and Social Council, considering (1) that a certain number of research activities can only be conducted in a rational manner on an international scale, and (2) that many branches of scientific research connected with the promotion of human knowledge, and especially with public health, would yield considerably more effective results if they were conducted on an international scale; invites the Secretariat to consult UNESCO and the other specialized agencies concerned, and to submit to the Economic and Social Council, if possible during the next session, a general report on the problem of establishing United Nations Research Laboratories."

Shortly after the above resolution had been passed, the Secretary General of the United Nations communicated with a number of agencies and international organizations, as well as with a special group of selected individuals, and requested them to submit their comments and suggestions.

The replies have been reproduced in a lengthy publication issued by the Economic and Social Council (Number E-620; Jan. 23, 1948).

In the realm of the physical and natural sciences, there are several independent suggestions for the establishment of international laboratories. A strong case is made for a number of international floating laboratories and attention is drawn to the value of international institutes of oceanography and fisheries. By a vote of the Economic and Social Council the United Nations is already committed to participation in attempts to coordinate world-wide cartographic services. The International Civil Aviation Organization, while registering itself as opposed to the establishment of international aerodynamical laboratories, goes on record as highly in favor of one or more international institutes for cartography and meteorology. Much useful work appears possible at international high altitude observatories specializing in the study of cosmic rays and of solar-terrestrial relationships. The project of an international astronomical observatory for the southern hemisphere appears to have the unanimous support from astronomers the world over.

In the area of the social sciences, emphasis is placed upon the need for an Institute of Human Relations. Such an institute is needed if the United Nations is to profit to the fullest by the application of the existing knowledge and techniques in the fields of psychology, sociology, and anthropology. The Society for the Psychological Study of Social Issues has prepared a comprehensive report on the International Institute for Human Relations. Some of the projects suggested to the United Nations are studies of mass psychology, of social tensions between peoples, and of children who are victims of war. Studies dealing with nutrition and housing are also

recommended. Finally, a good case is made for the sociological and scientific study of the potentialities of the hot and humid tropical regions.

Among the arguments in favor of the establishment of certain of these institutes are: (1) that they would serve the people of the region; (2) that they would promote a higher standard of living, especially in some of the backward areas; (3) that they would foster closer international cooperation; (4) that they would have symbolic value for the United Nations; and (5) they would enable the scientists from less privileged nations to have access to as good research equipment as their colleagues from the richer nations. There seems to be general agreement that the international institutes should not replace existing laboratories and observatories and that their establishment is justified only in cases where the need really exists and where there is no prospect that the institute would be established soon under different auspices. It seems to be further agreed that healthy national competition should not be stifled that the UN should not become a large benevolent foundation, and that support must not be withdrawn from existing centers.

The arguments against the establishment of international laboratories suggest: (1) that it might be preferable to offer support through the existing national and international organizations; (2) that there are too few scientists and that the staffing of the international institutes would drain still further the meager supply of scientists now available for research in national institutes; (3) that in some fields, like mathematics, there is very little need for international institutes; and (4) that it is premature to think of the establishment of international institutes at the present time.

Thermodynamics in Terms of Matter, Radiation, and Space

By ERNEST M. FERNALD

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I. Three Viewpoints

The ensuing remarks stem from belief that sundry concepts of classical or macroscopic thermodynamics look better when illuminated from a direction other than the usual ones. In this connection I shall first point out three distinct points of view open to those who would deal with energy; second, I shall set forth some virtues of a thermodynamic scheme based on matter, radiation, and space; and third, I shall comment adversely on the widely taught definition of energy as ability to do work.

Two of the three points of view referred to relate to Joule's experiments of 1840–48, undertaken to verify suspicion that heat and work were different aspects of the same thing. Among other activities, Joule stirred water and discovered—to use modern figures—that 778 foot-pounds of work used in stirring produced the same effect as did one British Thermal Unit of heat. The foot-pound and the British Thermal Unit already were established units of measurement, the one in Mechanics and the other in Calorics. The philosophical aspect of Joule's work is most clear from Fig. 1. His apparatus is denoted by a rectangle; a stream of mechanical effect flows into it from the left, and a stream of thermal effect flows out of it toward the right. Since part of the stream of total existence flowed through that apparatus, we may write "Past" over at the left and "Future" at the right. A curious misconception has arisen that Joule determined the mechanical equivalent of heat; what he actually determined was obviously the thermal equivalent of work. In general terms, he established the invariance of a total. The name chosen for this total was *energy*. Its formal definition is influenced by the definer's point of view. He that takes the stand indicated by A in Fig. 1, facing left, sees mechanical effect and accordingly defines energy as ability to produce mechanical effect, or as ability to do work. He that stands at B, facing right, sees thermal effect and defines energy as ability to produce thermal effect. Since 778 ft.–lb. = 1 B.T.U., it might seem immaterial which viewpoint is adopted, but we shall see later that it is by no means immaterial.

The third viewpoint referred to might be illustrated by a closed compartment with the observer inside. He lays down for himself certain rules of procedure and sets up thermodynamic schemes in accordance therewith. Keenan and Shapiro (1) have splendidly summarized four of these schemes. Strict logic prevails, with

meticulous regard for number of basically independent quantities, proper definitions, and so on. Such terms appear as "adiabatic wall" and " zero-work wall"; energy enters as "increment of property E." The place of such thinking in thermodynamics would seem to parallel the proper place of logic in the life of an individual, which is to report on compatibility among choices toward which his intuition, conscience, and esthetic sense impel him. Logic is never adequate basis for any one belief, but helps greatly in appraising the wisdom of trying to live according to two or more particular beliefs held simultaneously.

II. Thermodynamics in Terms of Matter, Radiation, and Space

Among the three viewpoints illustrated, I incline to B of Fig. 1, which seems to have been curiously neglected. I accordingly follow the path that starts from definition of energy as ability to produce thermal effect; specifically, radiation. The resulting thermodynamic scheme has three basic elements: matter, radiation, and space. For the time being disregard atomic fission, chemical reaction, electric and magnetic charge. They can readily be fitted into the final structure. There should be no quarrel with the statement that local mechanical effect tends to be translated into increased capacity for radiation. When friction operates between two bodies in relative motion, both become warmer and acquire ability to radiate; for example, to surroundings with which they were initially in thermal equilibrium. Also, bodies such as the earth radiate continuously into space. Imagine two bodies in otherwise empty space. They would radiate until each came into thermal equilibrium with empty space; or, as we commonly say, reach absolute zero of temperature. Then imagine that under gravitational influence the bodies collide. A big flare-up ensues, and more radiation. At the end, there is one body at absolute zero. The material substance we have been considering has reached the end of a road; it is now in equilibrium with empty space in respect to heat and work. In arriving there it poured out as radiation all its capacity to produce thermal or mechanical effect. Bear in mind, of course, the several items which are being disregarded for the moment. A formal definition for energy is accordingly set up as follows:

> Energy comprises radiation and capacity of matter to give rise to it, immediately or ultimately.

This definition says nothing about invariance of amount. With atomic fission and its converse ruled out, we have the traditional separate laws of conservation for matter and energy. Alternatively, we have the Einstein equation $e = mc^2$.

With matter and energy taken care of as to quantity by separate laws of conservation or otherwise, we examine

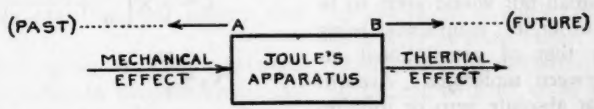

Fig. 1. Diagram Illustrating Important Philosophical Aspects of Joule's Experiments.

their respective trends. Two parallel laws of trend suggest themselves:

MATTER TENDS TO CONCENTRATE.
ENERGY TENDS TO DISPERSE.

To say that matter tends to concentrate is merely to affirm universal gravitation. Dispersal as the trend for energy follows from the view that energy as we have defined it has radiation for its ultimate end; and radiation does tend to disperse. All spontaneous processes that I have examined are in accord with one or both of these trends, and all versions of the Second Law with which I am familiar are corollary to them. Examples will be given later on.

The two laws of trend have certain implications concerning gases, especially with respect to behavior at very low temperature. At first glance, the gaseous phase appears to be an anomaly. Gas is matter, yet it tends to push out of its container and disperse. Anomaly disappears, however, in the light of common experience that gas comes into being through addition of heat to solid or liquid. Gas is matter sufficiently energized that the trend of energy toward dispersion comes into play. The trend of matter toward concentration is not lost, however, else the gaseous envelope of atmosphere would not hug the earth. According to these ideas, matter will not be gas when it has little or no internal energy; matter at or near absolute zero should be solid. From all accounts, it is. The amount of energy required to sustain matter in the gaseous phase is undoubtedly small but would seem to be finite, its order of magnitude being presumably that of gravitational attraction between molecules. Accordingly, gas at absolute zero or infinitesimally near to it becomes inadmissible —even theoretically conceived "prefect" gas.

One who thinks in terms of the laws of trend should be prepared to show that any spontaneous process results in concentration of matter, dispersion of energy, or both. He requires a general mathematical expression for concentration of energy, whose value should decrease in all spontaneous processes. I'm not sure that I have the final answer on that. I do have an expression that is plausible and that works for diffusion of gases and for radiation between bodies at different temperatures. Its basis is the obvious U/V, in which U denotes internal energy and V denotes volume. Applied to diffusion of gases it works this way. Before diffusion, concentration in the system is given by the weighted average

$$C=\frac{(U_1/V_1)\times U_1+(U_2/V_2)\times U_2}{U_1+U_2}.$$

After diffusion, U_1 and U_2 are each distributed throughout the total volume so that for equilibrium

$$C_e=\frac{U_1+U_2}{V_1+V_2}.$$

These concentrations are most easily compared if we let

$$U=U_1+U_2,\ U_1=mU,\ U_2=(1-m)U,$$

$$V=V_1+V_2,\ V_1=aV,\ V_2=(1-a)V.$$

The following expressions result:

$$C=\frac{U}{V}\times\left[\frac{m^2}{a}+\frac{(1-m)^2}{(1-a)}\right],$$

$$C_e=\frac{U}{V}.$$

Since the limiting values for both

and a are 0 and 1,

$$\frac{m^2}{a}+\frac{(1-m)^2}{(1-a)}$$

is equal to or greater than 1. Accordingly,

$$C-C_e=\frac{U}{V}\times\left[\frac{m^2}{a}+\frac{(1-m)^2}{(1-a)}-1\right]$$

is equal to or greater than 0. Except where $C - C_e$ equals zero, this shows that concentration of energy decreases in diffusion and that dispersion accordingly increases, as it should. $C - C_e$ equals zero when m equals a. U_1/V_1 then equals U_2/V_2, as for bodies of identical gas at equal pressures and temperatures. Therefore, when such bodies diffuse into each other, there is no change in concentration of energy, indicating that nothing has happened along the path of trend. Since change of concentration of energy in diffusion of unlike gases is proportionately related to initial dissimilarity with respect to U/V, equivalent of the Gibbs paradox does not arise.

A rather interesting question does arise, however. Can non-identical gases have equal U/V when pressures and temperatures are equal? The foregoing mathematics indicates that they cannot. This sweeping hypothesis I must leave to others; I do not feel capable of dealing with it. I do notice, however, that Schroedinger (2) deals with diffusion and the Gibbs Paradox in terms of quantum levels without reference to like or unlike chemical constitution. Should parallel reasoning on the macroscopic level require more data than internal energy and volume?

Consider now radiation between bodies at different temperatures. All energy concerned in diffusion is free to travel throughout the total volume. In contrast, radiation between two bodies initially at different temperatures requires that two particular quantities of energy be regarded as bound to their original volumes. These quantities are (1) all the original energy of the low-temperature body and (2) the fraction of the original energy of the high-temperature body that must still be in it at equilibrium. Only certain excess energy of the hotter body is free to travel into the volume of the other body. As a rough but sufficient approximation, we may say that the original energy of the hotter body spreads over more than its original volume. Denote this larger volume by $(1 + b)V_1$. Individual concentrations for the two quantities of energy are then:

Initial: U_1/V_1 and U_2/V_2,

Final: $U_1/(1+b)V_1$ and U_2/V_2.

Final weighted average concentration would obviously come out less than initial. Thus, two spontaneous processes—diffusion of gases and radiation between bodies at different temperatures—appear susceptible to mathematical treatment that yields decrease in concentration of energy, as required by energy's trend.

A few words now about the Second Law. One corollary of any law of trend is that no agent can exist that could offset, neutralize, or upset it. An engine that could deliver as work the full equivalent of heat supplied to it is accordingly deemed impossible. Such an engine could, for example, take in heat from a body and dissipate its equivalent in work through friction in a body at some higher temperature. Operating thus, and without net change in the engine itself or in anything else except the two bodies mentioned, it could offset, neutralize, or even re-

verse the natural trend for energy to flow from higher to lower temperature. The impossibility of this is one current version of the Second Law. Other versions are similarly arrived at on basis of one or both laws of trend, all being very close together in thought.

Especial attention should be given to theoretical apparatus required under particular definitions of energy. This apparatus must be capable of rendering all energy supplied to it into the form in which energy is defined—absolutely all of it. For definition of energy in terms of radiation, the apparatus is outstandingly simple. It comprises only empty space and means for measuring radiation. Both are admissible although extrapolated concepts; that is, concepts extended beyond what we have actually experienced or built. In terms of radiation, ordinary internal energy is equal in most cases to whatever radiates to empty space while volume is constant; if the body concerned arrives at absolute zero under pressure or in tension, there is an additive correction in the form of radiational equivalent of work done in expanding or contracting to reach the pressure of empty space. This work can be conceived as returned to the body and dissipated therein through friction, the resulting internal energy being radiated. In this scheme, a body has zero internal energy when it is in equilibrium with empty space in respect to radiation and work. Note that internal energy so defined does not include the zero-point energy of atoms at absolute zero. It does account for a large and readily separable block of energy possessed by matter. The list of conveniently separable blocks would thus start out:

(Kinetic) + (Gravitational) + (Internal) + (Subatomic) + ...

III. Energy as Ability to do Work

When energy is defined as ability to do work, internal energy is necessarily equal to whatever work is derivable from a theoretical engine in heat-transfer relation with the body whose internal energy is being measured. Obviously, no more could be supplied as heat to any engine than could be radiated to empty space. As the limit, therefore, the engine will receive the exact quantity defined as internal energy under the radiation scheme. I maintain that without violating the Second Law no engine could, even as theoretical limit, deliver all this quantity as work.

If energy subdivides infinitesimally, the engine would be able to violate the Second Law on finite scale while approaching its theoretical limit on infinitesimal scale. For example, it could transfer finite quantity of energy from a body at 500° to one at 1000° with expenditure of infinitesimal quantity received at 500°. In doing this, it would take heat Q from the body at 500°, reject dQ through radiation to empty space, and dissipate work $(Q - dQ)$ through friction in the body at 1000°. Since our electrical power is ultimately given to the atmosphere as heat, such an engine could take in heat from the atmosphere and run all our electric-light plants forever at the expense of infinitesimal net energy radiated to empty space. Under any meaningful interpretation, this is a violation of the Second Law.

Under quantum subdivision of energy, the engine gets impaled on one or the other horn of a dilemma. The amount of energy that the engine would receive above the datum of equilibrium with empty space would be n quanta, in which n is whatever number applies. If the engine delivered all

these n quanta as work, quantity of measured energy would come out equal to that under the radiation scheme, but the engine would violate the Second Law. The nearest it could come to not violating the Second Law would be to deliver $(n\text{-}1)$ quanta as work and simultaneously radiate one quantum. Internal energy as defined under the two schemes would thus come out finitely different by one quantum per body. This might be admissible, and competing definitions for energy merely result, were the energy-as-work scheme not thereby rendered hopelessly inconsistent. For example, measurement of aggregate internal energy of a thousand bodies would require radiation from the engine of 1000 quanta if the bodies were operated on separately, but radiation of only one quantum if they were combined into a single body. The scores for internal energy would come out different by 999 quanta. Accordingly, this engine leads only to violation of the Second Law and unseemly confusion with respect to amount of internal energy. For better or worse, energy as ability to do work seems firmly tied to such an engine.

The fundamental defect in the situation is rather clear in the light of the three points of view mentioned at the outset. It is a matter of orientation. Energy has been defined in terms of subsequent effect. The observed trend of the universe is against that effect's being work, but in favor of its being radiation. The dice are hence loaded from the start against energy as ability to do work. It seems fair to say that definition of energy in terms of work pertains to a world that runs backwards with respect to ours, and that increments of property E start out, at least, in a world that has no impulse to run at all. In contrast, definition in terms of radiation reflects the drive of the world which is. It should be especially congenial to those who prefer to have the flavor of actual existence pervade their thought.

IV. Summary and Conclusion

Enough having been said to exhibit general structure and important implications, the proposed scheme may be summarized.

1. The thermodynamic universe is conceived in terms of matter, radiation, and space.
2. Energy comprises radiation currently in transit and capacity of matter to give rise to radiation.
3. Neither matter nor energy can be created or destroyed.
   A. Alternatively, $e = mc^2$.
4. Matter tends to concentrate: energy tends to disperse.

The scheme is simple, is in excellent accord with observed ways of the universe, and has pleasing symmetry of structure. It is readily teachable on an elementary level. This scheme, especially its laws of trend, appears adequate whether or not matter is transmuted into radiation through atomic fission, or radiation into matter through decay into cosmic dust. Its basis of matter, radiation, and space is fundamental and comprehensive.

In closing, I freely grant that my presentation does not meet all requirements of scholarly logic as illustrated, for example, in the excellent paper by Keenan and Shapiro. I have not formally defined every concept employed or indeed anything except energy; I have not set up a scale for temperature; I have not even mentioned entropy. From one point of view,

therefore, the job is not complete. It is complete, however, with respect to contribution from a particular species of talent. I have conceived a design and, operating like a dress designer, have draped the material and pinned and basted it here and there. Seams are still to be sewn, buttons affixed, and so on. If some logical scholar likes the design, he will doubtless go on from where I leave off, which is right here.

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